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OPERATIONAL SUITABILITY GUIDE

Volume I - A Tutorial

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THE OFFICE OF THE DIRECTOR OF OPERATIONAL TEST AND EVALUATION

THE OFFICE OF THE SECRETARY OF DEFENSE
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Volume I of the Operational Suitability Guide was prepared by the Office of the Director of Operational Test and Evaluation (DOT&E) to provide an overview of those issues that are included in the general subject of operational suitability, and to provide background information for DOT&E Staff Assistants to use when examining operational suitability subjects. The document discusses each of the operational suitability elements, i.e., reliability, maintainability, safety, human factors, availability, logistic supportability, etc.; the parameters used during OT&E for each element; and key points to be remembered in the area of each element. The report includes as an appendix the Service Operational Test Agencies (OTA) Memorandum of Agreement on Common Reliability, Availability, and Maintainability Terminology. (KR)

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FOREWORD

The effective operational test and evaluation (OT&E) of defense systems is a critical part of the long-term program to provide for the proper defense for the United States. The Department of Defense has an established process for planning and conducting operational tests and for evaluating the data that result from those tests.

Volume I of this Operational Suitability Guide was prepared by the Office of the Director of Operational Test and Evaluation (DOT&E) to provide an overview of those issues that are included in the general subject of operational suitability, and to provide background information for DOT&E Staff Assistants to use when examining operational suitability subjects. This volume serves as a tutorial for OT&E personnel.

Volume II, OS Source Documentation: Supporting References, focuses on the review of specific OT&E documents and coverage of operational suitability in those documents. The information in Volume II is intended to supplement the policy and procedures contained in DoD directives and manuals. This document does not establish new requirements for operational test and evaluation documentation.

Volume I is organized in the following manner. Chapter 1 discusses operational suitability in general, and includes a detailed discussion on each of the elements that are listed in the definition of suitability. Chapter 2 discusses additional issue areas that deserve emphasis. Chapter 3 contains Annex A to the Operational Test and Evaluation Agencies (OTAs) Memorandum of Agreement (MOA) on Multi-Service OT&E. This annex comprises a listing of "Common Reliability, Availability, and Maintainability (RAM) Terminology," including common RAM parameters and a listing with definitions of the other RAM terms used by the Services.

If questions or comments arise while reviewing or using this guide, they should be forwarded to the primary author:

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Chapter 1

OPERATIONAL SUITABILITY

INTRODUCTION

Operational suitability is defined as

the degree to which a system can be placed satisfactorily in field use with consideration given to availability, compatibility, transportability, interoperability, reliability, wartime usage rates, maintainability, safety, human factors, manpower supportability, logistics supportability, documentation, and training requirements.

The suitability elements listed in this definition are discussed on the following pages. However, the definition lists only some of the items that may be suitability issues for a particular system; additional issues may be dictated by the system's mission(s) or the planned logistics support process that, during operational test and evaluation (OT&E) planning, may need to be considered. Chapter 2 discusses five of these additional issues: suitability modeling and simulation, integrated diagnostics, environmental factors, electromagnetic environmental effects (E3), and software suitability.

Chapter 1 and 2 are organized to present, as sub-sections, a definition of each suitability element or issue to be discussed, some of the parameters that apply, and key points that must be considered in its application to operational suitability. Key points and milestone activities that serve to support the overall operational suitability aspect of OT&E are set forth below.

KEY POINTS

Effective systems must be suitable.

Poor suitability may preclude the use of an otherwise effective system in combat. Any limitation that suitability imposes on the effective employment of a weapon system must be identified and evaluated. The suitability portion of OT&E must be planned and conducted to determine what, if any, limitation is likely to exist when the system is placed in operation.

Suitability issues that have the highest risk must be identified.

While all suitability issues must be satisfactory, the risks associated with these issues vary. The array of suitability topics for an individual system usually involves a number of suitability critical operational issues (COIs). Identifying these critical issues allows focus and attention to be directed to those areas in need of detailed and careful examination. Developing this focus is an essential part of the early Service planning of every OT&E. Independent examination of the system description, mission description, and planned support concept by the DOT&E staff provides the basis for evaluating Service-identified critical suitability issues.

KEY POINTS (Cont'd)

The operating scenario drives the suitability demands.

The demands for maintenance and supply support depend on the intensity of the system's use. Operating hours per day, miles per day, flying hours per day, that portion of the operation conducted at high speed conditions, any ratio of different mission types, etc., all are important factors for estimating the intensity of operational use. These factors must be estimated for the planned operational scenario and then considered as part of the Services' planning for the operational testing. The Services specify these mission parameters and scenarios in various documents, e.g., Operational Mode Summary. The way in which the system is used during operational testing, including the realism of the mission scenario(s) and the environmental conditions, is critical to constructing a test program that provides realistic operational suitability demonstrations and produces realistic suitability test data.

Terminology needs to be consistent.

Table 1-1 presents a hierarchy of terminology that relates the conduct of OT&E, i.e., characteristic, parameter, threshold. The evaluation of operational suitability involves selecting and examining *characteristics* that relate to each of the suitability issues. The characteristics for each of the issues are selected, considering the system's operating and support scenarios and the relative criticality of the areas included in each of the issues. As part of the planning for operational test, each characteristic will have one or more *parameters* identified. To evaluate the data that result from the operational tests in each of these areas, the parameter measurements must be compared to *thresholds* that were previously established. The table includes an example of how these terms might be applied when reliability is an operational suitability issue.

Table 1-1 Hierarchy of Terminology

TERM	EXAMPLE
Characteristic	Mission Reliability
Parameter	Mean Time Between Operational Mission Failure (MTBOMF)
Threshold	MTBOMF Shall Be at Least 300 Hours

There are always limitations to operational testing.

Resource and safety constraints often impose limitations on the conduct of the testing. The number of test articles available, the number of test hours, the availability of all support systems, and the realism of the logistics system almost always are limited. The importance of these limitations and their effect on the suitability results must be addressed in the Test and Evaluation Master Plan (TEMP), test plan, and test report.

Operational suitability applies to each level of support.

The Services use various support structures (i.e., levels of support) for weapons systems. Table 1-2 presents some examples of the levels of support that may apply. For most systems, the suitability elements (e.g., maintainability, training, documentation) apply differently to each support level. While only the first and second levels of support may be available at the operational test site, the evaluation should consider, if possible, all applicable support levels.

Table 1-2 Variance in the Definitions of Support Levels

Level	Type of Support	Example		
		A	B	C
1st	Owner or User	Organizational	Crew / Unit	Crew / Unit
2nd	Supporting Unit(s) with More Capability	Intermediate	Direct Support	Direct Support / General Support
3rd				

KEY POINTS (Cont'd)

Operational suitability has many dimensions.

It is impossible to combine the many quantitative and qualitative aspects of suitability into a single measure -- the unique aspects of each system impose a different priority on the suitability issues. The overall assessment of a system's suitability is an expert judgment based upon a multitude of factors. The suitability evaluation must assess what the OT results say about the likelihood that the system can be satisfactorily placed in field use in the intended operating environment. If an area of suitability is less than the level stated in the requirements, the evaluation should estimate the impact of this deficiency on the system.

MILESTONE ACTIVITIES

During the early system definition studies and analyses, the critical operational issues (COIs) in the suitability area should be identified. The initial Test and Evaluation Master Plan (TEMP) should discuss these issues. The characteristics that relate to COIs should be identified by Milestone I, the Concept Demonstration/Validation Decision. The system mission profile(s) and life profile also should be defined by Milestone I and documented in the Operational Mode Summary, or similar document. (The life profile is a time-phased description of the events and environments that an item experiences from manufacture to final expenditure of the item or its removal from the operational inventory. It includes one or more mission profiles, in addition to any storage, transportation, maintenance, or exercise events and environments that the item will experience.) The early definition of these profiles does not imply that the profiles are "in concrete" and will not be revised.

By Milestone II, the Full-Scale Development Decision, the program manager and the developing contractors should have a reasonably well defined "system-level" design. The required level of reliability and maintainability should be known. The maintenance diagnostics approach, the maintenance concept, and the general level of support requirements should be established. The training concept should be understood. The relationship between the system's reliability and maintainability requirements and the maintenance concept should be defined and in balance with the planned logistics support concept. High reliability systems can be supported with unique logistics support systems, e.g., missiles that are handled as "wooden rounds." (A "wooden round" is a missile or munition that is handled in the operating unit as a single assembly. There is no plan or capability to isolate faults or to disassemble the item at the operating unit.) Weaknesses in these areas or lack of detailed knowledge may cause problems as the program proceeds. Lack of definition at Milestone II also may result in the developing organizations or contractors having differing views of some aspects of the program. This can lead to inconsistency between the support planning and the system's detailed design. The definition of the system and its support concept are needed to define the OT&E criteria and produce the Milestone II TEMP.

If there is a Milestone IIIA (the Low Rate Initial Production (LRIP) decision), an operational assessment report or the first of the OT&E reports should show the status of the system in meeting its operational suitability requirements and satisfactorily resolving the suitability issues. Testing should be complete in some operational suitability areas, and results compared to the criteria and the evaluation results reported during the Defense Acquisition Board (DAB) process.

The CT&E report that supports Milestone IIIB (the Full Rate Production Decision) should update the previous information and (if not complete) should have an expanded evaluation of operational suitability subjects. The test and evaluation report should compare the results to the threshold, highlight the current "status" of the system, and describe areas that have changed status, i.e., from "deficient" or "unsatisfactory" to "satisfactory." This report should contain the final assessment of the question, "Is the system suitable?"

Availability is defined as

a measure of the degree to which an item is in an operable and committable state at the start of a mission when the mission is called for at an unknown (random) time.

This definition of availability addresses systems that spend a portion of their time in a "ready" status, and at some undetermined time are required to initiate a mission. The discussion of a system's availability must consider the type of system being considered. Items being operationally tested range from entire aircraft, to complex ship combat systems, to relatively small man-portable systems and items that are only part of a complex combat system. Some systems spend most of their time in a readiness status, always available to perform a single mission (e.g., a strategic missile system). Other types of systems with other operating scenarios require other measures. Some are "continuous-use" systems that are required to perform twenty-four hours a day (e.g., command and control computer systems, communications systems, or warning systems). Other systems spend time in a ready status and perform repetitive missions when called upon (e.g., tactical aircraft). In many cases, the call to perform a mission is not necessarily random; the operational commander exercises some control over when the particular system is required to perform a mission. Because of the degree of control over the scheduling of tactical aircraft sorties, some aircraft systems are better characterized by using "sorties per aircraft per day," or "sortie rate," as a measure of how available the system is to perform its mission. The probability of being available for the first mission may be very different than the probability of being available for second and later missions. Examination of the availability for each of these cases requires consideration of the different perspective in each case. In some cases, manpower levels may limit availability.

PARAMETERS

The multi-Service memorandum of agreement (MOA) (Chapter 3) has two definitions for operational availability, A_o. The first is

$$A_o = \frac{\text{Total Uptime}}{\text{Total Uptime} + \text{Total Downtime}}$$

when operated in an operational mission scenario. The second is

$$A_o = \frac{\text{Number of systems ready}}{\text{Number of systems possessed}}$$

The first equation can be used during the OT of subsystems, and in situations where it is possible for the system to be in a state other than "up" or "down." An example would be a situation where there is an interruption of the testing for redeployment of the test forces, system reconfiguration, or other activity. The operational test plan must state clearly how these periods of "no test" are defined and who will determine when these periods start and stop.

The Services use other methods of calculating the ratio of availability. For some Army and Marine Corps systems, the A_o is calculated by an expanded equation

$$A_o = \frac{\text{Operating Time} + \text{Standby Time}}{\substack{\text{Operating Time} + \text{Standby Time} + \text{Total Corrective Maint. Time} \\ + \text{Total Preventive Maint. Time} + \text{Total Administrative and} \\ \text{Logistics Downtime}}}$$

At other times, the Services may use parameters such as the percent of time that the system is Mission-Capable (MC), Full Mission-Capable (FMC), and Partial Mission-Capable (PMC) as measures for availability. These measures are dependent on the list of system equipment that is essential for each system's missions. (A full listing of mission-essential equipment should be contained in the TEMP, or included by reference.) By definition,

> a system is "Full Mission-Capable" when it has all mission-essential equipment available and can perform any of its missions;

> a system is "Partial Mission-Capable" when only a portion of the mission-essential items are available, but can perform at least one, but not all, of its missions;

> a system is "Mission-Capable" when it is in either a PMC or FMC condition;

> "Not Mission-Capable" means that the system does not have the equipment available to perform any of its missions.

One of the advantages of these parameters is that they may allow OT&E results to be put into terms that are familiar to operational commanders.

Another availability measure is achieved availability. This parameter may be used in situations where the test is limited in the logistics area. It is very costly to procure spares or to have a representative logistics system for engineering development models (EDM) or for situations where two or more contractors are competing by producing competitive systems that are to be evaluated in an operational test. When the supply support is limited and nonrepresentative, the total administrative and logistic downtime component of operational availability cannot be evaluated. Achieved availability does not consider the downtime associated with logistic or administrative delays. The equation for achieved availability is

$$\frac{\text{Achieved}}{\text{Availability}} = \frac{\text{Operating Time}}{\substack{\text{Operating Time} + \text{Total Corrective Maintenance Time} \\ + \text{Total Preventive Maintenance Time}}}$$

Another parameter for availability relates to the percentage of time that an item is able to satisfy a demand for its service. This parameter may be applied to systems that are drawn from storage or from a stockpile, or to systems that are maintained in a standby state and then called on to support a mission at a specific time. Demand availability is usually expressed as a percentage.

$$\text{Demand Availability} = \frac{\text{Number of times available}}{\text{Number of times requested}}$$

Additional parameters for availability are listed in the multi-Service MOA (See Chapter 3).

KEY POINTS

Availability is a critical characteristic that should be discussed in the early planning documents.

The early system planning documents should provide a basis for relating availability to other system characteristics as the program proceeds through later acquisition phases. The system requirements should identify which availability parameter is most meaningful for the system. How this parameter relates to the operating scenario and the reliability and maintainability parameters needs to be understood.

System availability is difficult to measure during short operational testing periods.

During operational testing, the measured value for availability can be totally unrepresentative of what might be expected in operational service. For example, in a short test period, only a few failures may occur. As this may not be a representative number of failures, the resulting calculated availability may be very optimistic. For an immature system, the time to identify problems and restore the system to an operational status may be extremely lengthy. In these cases, the limitations on the availability measure must be recognized. In addition, the planned maintenance and supply systems may not be in place because the system is not yet fielded and may not be fielded. Modeling and simulation may be useful in assessing the availability in these situations.

The OT planning should address the methods of measuring times for the availability evaluation.

The way in which a system is to be used in operation will determine the most appropriate availability parameter. How that parameter is applied to the system in question will help establish how the system's operational time is recorded and evaluated. If the system has standby time, or time that will not be included in the availability calculation, then the test planning should address the specifics of how these items will be handled. If the OT is to include periods during which the measure of time is not to be included in the availability evaluation, then the test plan should address the definition and likelihood of "no test" time, and indicate how this time will be addressed in calculating operational availability.

System standby time may be important.

If system standby time is included in the calculation of availability, then the ratio of the standby time to active system operating time should be assessed for "reasonableness." If an unreasonably high ratio of standby time to system operating time is evident in the test, then the calculated operational availability will be unrealistically high. An estimate of the ratio that will be observed in combat operations should be described in the Operational Mode Summary, or similar documents. The planning for the operational testing should address what ratio is planned for the testing period, and how this compares to the estimated ratio for operational use.

Logistics support realism should be an objective in planning for operational testing.

To provide useful insight into the operational availability of the system being tested, the logistics support being provided during the testing should be as realistic as possible. Any limitations that exist need to be identified prior to the test, and included in the evaluation of test results.

$$\text{Mission Reliability} = \begin{array}{c} \text{Probability of completing a mission of} \\ \text{X hours without a critical failure;} \\ \text{under specified mission conditions} \end{array}$$

$$\text{Probability of Success} = \frac{\text{Number of successful attempts}}{\text{Total number of attempts}}$$

Mission reliability also can be stated as Mean Time (Miles, Rounds, etc.) Between Operational Mission Failure (MTBOMF). This parameter can be used for continuously operating systems, such as communications systems, or for vehicles or artillery.

$$\begin{array}{c} \text{Mean Time Between} \\ \text{Operational Mission} \\ \text{Failure} \end{array} = \frac{\begin{array}{c} \text{Total operating time (e.g., driving time,} \\ \text{flying time, or system-on time)} \end{array}}{\text{Total number of operational mission failures}}$$

Another parameter that sometimes is used in place of MTBOMF is Mean Time Between Mission-Critical Failures (MTBMCF), which has a similar equation, substituting the term "mission-critical failures" for "operational mission failures." In both cases, the definition of what constitutes a "mission failure" must be clearly documented for the applicable system.

The parameter "Mean Time Between Failure" (MTBF) is being used less frequently during operational test and evaluation. One reason for this is the confusion that may exist between the use of MTBF as a technical parameter in contract documents or in DT&E, and the use of a similar parameter as an OT&E parameter. (The trend in the Air Force has been to reserve MTBF for DT&E and contract purposes, and to use other parameters with operationally oriented definitions in OT&E.) If MTBF is stated in a TEMP or OT&E plan, the definition of what is considered a failure must be included (or documented in a reference) in sufficient detail to ensure that it includes all operational influences, not just system or component design problems.

Logistics support frequency is measured as the time between events requiring unscheduled maintenance, unscheduled removals, or unscheduled demands for spare parts. These events are considered whether or not mission capability is affected. Logistics support frequency can be expressed as Mean Time Between Unscheduled Maintenance (MTBUM).

$$\begin{array}{c} \text{Mean Time Between} \\ \text{Unscheduled} \\ \text{Maintenance} \end{array} = \frac{\text{Total operating time}}{\begin{array}{c} \text{Total number of incidents requiring} \\ \text{unscheduled maintenance} \end{array}}$$

If MTBF is used as a measure of logistics support frequency, the definition must include any appropriate maintenance events that are not the result of failures such as preventive maintenance actions, inspections, calibrations, or no-fault-found actions. If these non-failure-caused maintenance actions are not included in the calculation of MTBF, then the MTBF may be significantly higher than a measurement of the MTBUM and is not a measure of logistics support frequency. Other logistics support planning such as manpower, spares, or the amount of test equipment will be understated if MTBF is assumed to be the parameter that determines the need for these resources.

Another logistics support parameter that is indirectly a measure of reliability is Mean Time Between Removal (MTBR). This parameter is used to measure the frequency of failures or maintenance actions that require some item of equipment to be removed from the end item. MTBR indicates the demands on the supply system for replacement items and for repair processing at the intermediate or direct levels of maintenance.

KEY POINTS

Reliability parameters should be defined early in a program.

By Milestone I, the critical reliability parameters should be set forth by the user or user representatives in the early planning documents. These descriptions are the basis for considering reliability and in relating it to other system parameters.

The system's operating modes can drive reliability.

System operating modes must be considered in determining the relative importance of mission and logistics reliability. Defense systems may be continuously operating, perform repetitive missions, or be one-shot items. The reliability parameter must be selected according to how the system is employed. Systems that are continuously operating may be measured by Mean Time Between Operational Mission Failures (MTBOMF). Systems that perform repetitive missions may also use this measure, or the probability of completing a mission without a mission failure.

Firm reliability requirements are essential.

Firm requirements must be established in the Service acquisition documentation for each of the applicable reliability parameters before Milestone II. The requirements have meaning only if they include a detailed, comprehensive failure definition that is consistent with what one would expect from an operational user. If there is an unusual exception (e.g., failures caused by crew error are not included), this exception must be clearly identified in the TEMP and the OT plans.

Reliability measurements can require lengthy test periods.

High reliability systems with lengthy times between failures require lengthy test times in order to gather sufficient test experience to produce meaningful measures of the system's reliability. If extended periods of test time are not achievable, then the OT&E must be structured to use other methods or sources of data to evaluate reliability. Modeling and simulation might be used to focus the operational testing on subsystems of greatest risk or criticality. The data of technical testing might be used to supplement data that are obtained during OT. In some instances, the only solution is to be satisfied with reduced confidence levels, since the cost of the test systems (e.g., complex missile systems) is too high to permit additional test articles to be expended.

Assumptions are made in reliability test planning.

Long test periods are needed to accurately measure reliability of high reliability systems. Sometimes a greater number of items are tested for a short time, instead of a few items for a longer time. For example, a good test program for a system with a MTBOMF of 1000 hours might be to test some number of systems (e.g., four) for 1000 hours each. Because the long test period needed to obtain 1000 operating hours is not possible, the test is planned for twenty systems with 200 hours each. Although this will result in the same number of total operating hours, there are inherent risks. The DOT&E evaluator will need to determine the likelihood of significant "wear-out" failure modes -- are there significant failure modes that will not be seen until after the 200 proposed hours of testing? Assessing this risk requires an examination of the system. The responsible Service should demonstrate that the risk is acceptable by presenting other test data that demonstrate that significant "wear-out" failure modes have not occurred in longer duration testing, and are unlikely to occur in operation. If this cannot be demonstrated,

then alternative test approaches should be considered, e.g., testing a few items for a longer period, having test units tested for a longer period in other test phases, etc.

Early OT may give the first realistic view of system reliability.

Initial operational testing can provide insight into the reliability potential of the system. While it is difficult and time consuming to verify that a high level of reliability exists, the discovery of reliability deficiencies is not difficult if the system is truly deficient. An operational assessment may identify areas that potentially could become major deficiencies. A critical error at this stage is committed when the reliability data that are the result of early testing are not accepted -- failures are "explained away" and managers' projections that accept high reliability turn out to be too optimistic. On the other hand, the reliability and failure experience early in a development program may not be representative of the production configuration; the results indicated by early Developmental Test (DT) data may change significantly by the time the system reaches maturity.

If there are any deviations from the planned production configuration, they should be understood.

To evaluate the reliability of a system in its intended operational environment requires that the items being tested have a reasonable degree of agreement with the planned production configuration. All significant deviations from the production configuration should be identified.

Reliability measures can have statistical confidence calculations.

One measure of the sufficiency of the test data is the use of statistical confidence calculations. During the test planning, confidence calculations can be used to determine how much testing is needed to yield a certain level of confidence in the results. After the test data have been collected, confidence calculations can be used to indicate how adequate the data were in determining the values for the reliability parameters. A good reference for a discussion of confidence levels and intervals, and how they apply to the test and evaluation environment, is DoD 3235.1-H, "Test and Evaluation of System Reliability, Availability, and Maintainability - A Primer." It provides a reference for the mathematical aspects of RAM and discusses confidence as it applies to planning test programs and evaluating test data. The discussion is based on technical R&M characteristics and may require tailoring when applied to OT&E.

Software reliability is always an issue.

As defense systems become more and more software-intensive, understanding software's contribution to system reliability increases in importance. Software faults and errors can be a major problem during the initial phase of a system's operation, and they should be viewed within the context of what effect the faults will have on the system's performance. Serious faults can result in mission failures and should be treated accordingly. Easily corrected, minor interrupts that cause no system-mission impact may be significant only if the quantity is high enough for the problem to effect operator performance and attention.

Reliability growth programs are used in some DoD programs.

If the program manager has defined a reliability growth program, the projections from such growth programs should not be used as part of the operational evaluation. The potential growth of system reliability, during or after the completion of the operational testing, may not be easy to estimate; it is dependent on resources, dedication, and many technical details. If a projection is needed, it is preferable to use the reliability growth experience from similar systems as a basis for what has been done and what might be done on the system in question. A projection should never be reported as a test result. The test result should be an observed value.

1.3 MAINTAINABILITY

Maintainability relates to the ease and efficiency of performing maintenance. It is defined as

the ability of an item to be retained in or restored to specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair.

There are three important dimensions to the examination of system maintainability. The first is the average corrective maintenance time required to restore the system to its mission-capable condition. This maintainability characteristic gives a view of how long the system will be under repair after mission-critical failures. The average repair time for a system might be two hours. In this situation, the system would be unavailable due to maintenance for an average of two hours after each mission-critical failure.

The second dimension addresses the maintenance time required to restore the system after any failure that requires corrective maintenance. The average time to restore, considering all corrective maintenance, may be longer or shorter than the time for mission-critical failures.

The third dimension to consider is the manpower required to perform the repair function. If it takes two hours for the average repair, there is a considerable difference in the required support resources if the repair requires one technician or three technicians for this two-hour period.

PARAMETERS

A maintainability parameter that addresses the length of time required to restore the system to a mission-capable state is Mean Operational Mission Failure Repair Time (MOMFRT).

$$\text{Mean Operational Mission Failure Repair Time} = \frac{\text{Total number of clock hours of corrective, on-system, active repair time used to restore failed systems to mission-capable status after an Operational Mission Failure}}{\text{Total number of Operational Mission Failures}}$$

A parameter that addresses the time required to restore all failures is Mean Corrective Maintenance Time (MCMT).

$$\text{Mean Corrective Maintenance Time} = \frac{\text{Total number of clock hours of corrective, on-system, active repair time due to all corrective maintenance}}{\text{Total number of incidents requiring corrective maintenance}}$$

Another parameter that is used to address all corrective maintenance time is Mean Time to Repair (MTTR). The OTA MOA (see Chapter 3) has a number of definitions for MTTR. One definition is

$$\text{Mean Time To Repair} = \frac{\text{Sum of corrective maintenance times}}{\text{Total number of corrective maintenance actions}}$$

In addition to the average (or mean) time that is required, there are some systems where it is important to have a view of how many lengthy maintenance actions there will be, and the duration of those actions. In this situation, the parameter Maximum Time to Repair (MaxTTR) may be used. Maximum Time to Repair will give a time that a specified percent of the maintenance actions would be completed. For example, a MaxTTR might be specified for 90 percent of the failures. If the MaxTTR was four hours, this would mean that 90 percent of the maintenance actions would be completed before four hours elapsed.

To use parameters such as Mean Corrective Maintenance Time (MCMT), it is important to define the meaning of "corrective" versus "scheduled" or "preventive" maintenance, and also to define when each of the important time measures start and stop. For space systems and software-intensive systems, the parameter Mean Time To Restore Function (MTTRF) may be used.

$$\text{Mean Time To Restore Function} = \frac{\text{Total maintenance time to restore mission functions interrupted by critical failures}}{\text{Total number of critical failures}}$$

This parameter addresses both scheduled and unscheduled maintenance time.

Maintainability parameters that address the manpower resources required to perform maintenance include Maintenance Manhours per Operating Hour (flight hour, mile, round, etc.). For some systems, the maintainability (and the manpower required) is measured using a parameter of Maintenance Ratio (MR), which is a measure of the maintenance manpower required to maintain a system in an operational environment. It is expressed as the cumulative number of direct maintenance man-hours during a given period of time, divided by the cumulative number of system life units (such as hours, rounds, miles) during the same period. There could be a measure of MR for each maintenance level, and/or a summary for a number or all levels. The levels of maintenance are defined and labeled differently in each of the Services (see page 1-3). The man-hours considered usually include all types of maintenance, e.g., corrective, scheduled, preventive.

Maintainability also may include an examination of any automated system diagnostics. The label "integrated diagnostics" addresses all forms of diagnostics systems, including automatic, semi-automatic, and manual, built-in or stand-alone, in an integrated fashion. All faults and failures must be diagnosed by some method. The integrated diagnostics systems should be designed and tested to meet this need. Integrated diagnostics is discussed in section 2.2.

The maintainability of the software of certain systems also can be a critical issue. This topic is discussed in section 2.5.

KEY POINTS

Maintainability measurement requires a reasonable number of maintenance events.

Limiting the test period can limit the applicability of the maintainability results. To obtain a meaningful evaluation of system maintainability requires that the test data include a relatively good cross-section of maintenance actions that are expected to occur during the system's operational service. Examining only a few failures may exclude insight into a large portion of the maintenance training, maintenance documentation, etc. Sampling a number of maintenance actions can result in a maintainability evaluation that is significantly different than the actual capability of the system. One solution is a properly structured maintainability demonstration, but such demonstrations must be properly planned to produce results that are valid for supplementing operational test results.

Maintainability demonstrations can be used in OT&E if they are realistic.

A maintainability demonstration is an activity wherein maintenance tasks are caused to be performed and the personnel, test equipment, tools, etc., involved in the maintenance are evaluated by observation. Proper operational maintainability demonstrations must be structured so as to present a representative operational environment. Maintainability demonstrations routinely are used as part of the contract verification requirements imposed on the developing contractors, but the demonstration methods used there are not adequate for OT&E because they lack operational realism.

If maintainability demonstrations are used as part of the OT&E, the plan for these demonstrations should address the cross-section of maintenance tasks that are used, the personnel used in performing the maintenance, and the conditions surrounding the tasks used in the demonstrations. Maintenance events or tasks that are performed in operating units usually include events that are not the result of failures. Further, there are poorly documented symptoms, false alarms from the diagnostics system, and other types of tasks that may not be included in a task list that is provided by the contractor or the government program manager.

The best source of a realistic task list would be the product of having senior maintenance technicians from the relevant operating units modify the contractor's task list, based on maintenance tasks required for similar systems. These task lists can be used to identify pre-faulted modules that have been used as part of maintainability demonstrations. The personnel used in the demonstrations should be as representative of the expected operational personnel as possible.

The conditions attending the demonstration also should be realistic. It should not be conducted in a laboratory if the actual maintenance will be done in the field, in all weather, and under 24-hour-a-day lighting conditions. If maintenance tasks are to be performed while wearing chemical, biological, radiation (CBR) protective clothing, then the use of this clothing should be considered when planning the demonstration. The proximity of support assets, such as support equipment, documentation, etc., also should be representative of what might exist in an operating unit.

Built-in test equipment and other diagnostics systems must be properly tested and false alarm rates documented.

Built-in test equipment and other diagnostics systems must be tested properly, as they too may be fundamental to maintaining the system. This testing must not be glossed over, as is often the case. False alarm rates frequently are not discussed in test documentation and therefore make it very difficult to evaluate the BIT responses that occur during OT (see section 2.2).

Any routine scheduled or preventive maintenance should be carefully examined during OT.

The total requirement for scheduled or preventive maintenance can be significant for some systems. This significance may exist either in the total system downtime to perform the maintenance, or in the total number of manhours required. Routine maintenance events, such as changing oil in generator power supplies, should be examined for adequate accessibility. The "reasonableness" of the estimates for the total downtime or manhours expended in these areas should be examined. The time required for each of the significant scheduled maintenance tasks should be evaluated as part of the OT.

The time for off-equipment repairs can be significant.

One factor often overlooked in requirements and test documents is the criteria for off-system (or off-equipment) repairs. Mean time to repair (MTTR) usually applies to the time required to return the system to a mission-capable state. This may involve a change in a major system component. The time to repair applies to the time needed to isolate the failure to a component and to change the failed component, but does not involve the actual repair time to return the component to a ready-for-issue status. MTTR can be manipulated by a "shotgun maintenance" approach (e.g., removing and replacing the three or four most likely failure candidates), but such actions may go undetected if the removed parts are not tracked through the next higher level of maintenance. Further, this approach causes serious logistics concerns due to the quantities of good units being processed in the repair pipeline, tying-up maintenance resources later labeled as "Retest Okay" items. It also may have a major affect on the number of spares and how they are positioned.

An evaluation that addresses only on-equipment MTTR fails to consider the impact on the maintenance organization from the manpower and support equipment required to actually repair the item, and it does not consider the impact on the logistics system of the material needed to make the eventual item repair. Off-system repairs should be evaluated to determine the potential for unexpected levels of support costs. The inability to logistically support the system once fielded can be significant. To avoid this, off-equipment repair should be addressed in the requirements and OT&E documents.

Unique maintainability characteristics or requirements should be identified and included in the OT.

The system being tested should be examined to determine if there are any unique maintainability characteristics or requirements. Examples might be maintenance of nuclear hardness features or special features for battle damage repair. These unusual features should be considered when planning the maintainability activities for the OT.

Interoperability is defined as

the ability of the systems, units, or forces to provide services to and accept services from other systems, units, or forces, and to use the services so exchanged to enable them to operate effectively together.

In the context of operational suitability and OT&E, interoperability addresses the ability of the system to be used in concert with other types of systems and other systems of the same type that are necessary to accomplish the required mission or missions.

Interoperability is frequently considered to have an effect on both the suitability and the effectiveness of the system. Operational testing must be focused on those supporting or companion systems that are essential for the system under test to meet its operational requirements. During the early test planning, the critical companion systems must be identified and documented by the Service in the TEMP. The quality of the interoperation that must be examined by operational testing must be defined in detail in the OT&E test plan prepared by the OTA.

Interoperability recognizes that, for the system to perform its mission, there are functions that are performed by two or more items in concert. For example, data and communications systems must have the technical capability to interface and exchange data. Issues for these systems are usually resolved during technical testing, but operational testing may result in additional confidence in the interoperability or may provide additional and more realistic situations under which to assess the operation of the systems.

PARAMETERS

Interoperability usually is evaluated in a qualitative manner. However, there may be aspects that are described quantitatively and therefore contribute to the presentation of the system's interoperability status.

One way to describe the interoperability of a system being tested is to discuss what limitations the system imposes on operations when it is used with other systems. This would entail preparing the following:

- A list of those systems that will require special procedures when operated simultaneously with the system under test, and

- A list of those systems whose modes of operation must be changed when in the presence of the tested system.

KEY POINTS

Supporting or companion systems need to be identified in the early versions of the TEMP.

The identification of supporting or companion systems is one of the keys to conducting a successful evaluation of the system's interoperability. By Milestone I, the systems and equipments that will have critical interoperation with the system under test should be identified

and documented by the Service in the appropriate acquisition documents. The early versions of the TEMP should highlight these companion systems and the need to have the required test assets to verify interoperability.

The consideration of companion or supporting systems also should address other systems that are under development.

This consideration should include not only existing systems, but also companion systems that are being developed at the same time as the system being examined. There are frequently problems in acquiring test assets when systems are in the development stage. In such a case, conducting dual tests of two systems that are both being developed may be difficult, but the OT&E planning must address the need for examining any critical interoperability. If such dual testing is not possible, then the evaluation must discuss the likelihood of potential problems and the limitations to the OT&E because the two systems were not tested simultaneously.

Maturity of supporting or companion systems must be understood.

The relative maturity of the supporting or companions systems must be part of the assessment of what is needed during the OT. If these other systems are not mature enough to provide a realistic level of the planned support, the OT may provide invalid answers. Also, the likely maturity at fielding should be assessed. If the suitability of the system when fielded is dependent on supporting systems, e.g., targeting information systems, and the supporting systems are unlikely to be available to provide the required support, then this potential deficiency needs to be highlighted to the decisionmakers.

Determination of adequate suitability depends on the performance of the supporting systems.

When the suitability of the system under test is being determined, the acceptability of the supporting systems also should be part of the judgment. An example might be a targeting system for a missile system: if the targeting system cannot meet its projected requirements, then the missile system can hardly be expressed as being suitable.

Interoperability problems may cause system limitations.

One category of interoperability problems is a situation where a system must be limited in its operation due to the proximity to another system. Examples include a radio transmitter that must be turned off when near another type of radio or communications device; an aircraft that must fly at reduced speeds when in the company of another aircraft type; and a jammer that must be turned off if a radar is to work or if a certain missile is to be fired. Another example is the limitation on the use of viewing devices, low-light-level television, etc., if flares are to be used. Limitations to system operation that are the result of interoperability should be identified during OT.

Interoperability should be addressed in the OT&E prior to Milestone III.

By Milestone II, the TEMP should indicate the manner in which major interoperability areas will be examined under operational testing. The test resources description must indicate what companion or supporting systems are critical to the system in question. The test resource planners need to assure that these companion or supporting systems will be available for the test period.

1.5 COMPATIBILITY

Compatibility is defined as

the capability of two or more items or components of equipment or material to exist or function in the same system or environment without mutual interference.

Compatibility addresses and includes many different areas. It concerns the capability of the equipment in the system to operate with each of the required supporting equipments, e.g., electrical power generation, air conditioning, hydraulic power subsystem, as well as with other elements of the system. It also addresses the interface with logistics support items, including test equipment, servicing equipment, maintenance stands, handling equipment, and elements of the transportation systems (see section 1.7). Compatibility includes physical, functional, electrical and electronic, and environment conditioning areas. Human factors (covered in section 1.13), environmental factors (section 2.3), and electromagnetic environmental effects (E3) (section 2.4) also are compatibility considerations.

Physical compatibility involves attachment pins, connectors, the interconnecting wires, cables, alignment, and mechanical linkages. Physical compatibility may involve the ability to install the item in its assigned location, physical clearances, and item volume. These physical characteristics involve compatibility with other elements of the operational system, as well as equipment that is part of the logistics or maintenance environment. Electrical or electronic compatibility considerations include voltage, current, and the frequency for systems using alternating current. For radio frequency or visible light interfaces, a basic consideration is the frequency of the transmitted signal. Other factors considered include bandwidth, frequency hopping patterns, and signal polarization. Environmental conditioning considerations address the compatibility of heating and cooling subsystems. The cooling to be provided for electronics items must be consistent with the requirements of the system.

PARAMETERS

Compatibility parameters involve the measurement of many different aspects of the system's characteristics, as well as compatibility by function. While much of the detailed compatibility testing is the domain of DT, there is a need to monitor and assess compatibility during OT. Additional or expanded environments usually are present during the conduct of a realistic OT, and therefore there is some likelihood that problems not seen during DT may be uncovered in the operational testing.

Some of the parameters that may be considered during DT and/or OT include:

- Physical - Attachment pins and connectors, alignment, physical dimensions, volume, and weight.

- Electrical - Voltage, cycles, power profile or stability, and surge limits.

- Electronic - Frequencies, modes, rates, control logic, and telemetry.

- Environmental Conditioning - Heating, cooling, shock and vibration protection.

- Software - Formats, protocols, and messages.

- Hardware/Software - Conventions, standards, timing, sequencing, sensing, and control logic.

- Data - Rates, inputs, characters, and codes.

KEY POINTS

DT results may help focus OT planning.

Compatibility requirements should be monitored during the early development stages of the acquisition process to ensure all compatibility areas and issues are addressed. DT results should be tracked to assist in the OT planning and to avoid duplication of testing efforts.

Early operational testing may indicate unforeseen compatibility problems.

The early OT phase should include a compatibility issue to ensure that operational considerations introduced into the testing at this point are not causing problems that were not observed in DT. Identification of potential problems not anticipated by the designer could include electrical power variations, unexpected electrical interference, or the need for additional air conditioning.

Nominal operations may not expose incompatibilities.

Nominal operations may not expose interference or incompatibility problems, and special tests may be required to test the system in various modes and operational extremes to detect potential interference.

Operational test personnel must address the needs for any special resources/systems that are required for compatibility testing.

If special facilities, instrumentation, and simulators for compatibility are required for OT, advanced planning is required. These requirements must be discussed in early versions of the TEMP. Failure to do advanced planning may result in a delay to the operational testing, or in conducting the test without completing some of the objectives.

Modifications or upgrades may introduce compatibility problems.

The addition of new or advanced capabilities to a weapon system may introduce the potential for compatibility problems. For example, if a system is upgraded with more advanced computer and electronics systems, the original environmental equipment may be unable to provide adequate cooling to the new system. As a result, the new electronics will operate in higher temperatures and be less reliable than projected when used by the operating units. A similar situation may result with a ground combat vehicle that is upgraded with heavier weapons and, as a result, has a weight that may be incompatible with elements of the drive train, brakes, etc. The integration of non-developmental items (NDI) into a system also may introduce compatibility problems.

Compatibility of procedures can be a factor in system performance.

The compatibility of two systems may depend to a large degree on the procedures being used and how the procedures are followed. During the testing of one system, it was discovered that the main system was not compatible with the command and control system. The system was fired and controlled in a fully automated manner, while the fire support system was manually operated. The crews that were to make the manual-to-automated translations could not communicate inside some of the shelters because of the noise level that resulted from the support equipment (400-cycle cooling fans, and turbine generators).

1.6 LOGISTICS SUPPORTABILITY

Supportability is defined as

the degree to which system design characteristics and planned logistics resources, including manpower, meet system peacetime readiness and wartime utilization requirements.

This element addresses the balance between the system's support needs, which are a result of the system design, and the planned logistics support for the system.

Other suitability elements also address aspects of this balance, e.g., reliability, maintainability, manpower, documentation, training, and the like. The scope of logistics supportability within the OT&E documentation is limited to those aspects that are not covered under other topics. It also includes the integrated aspects of the logistics planning. Key items that should be addressed under this element include supply support (the planned numbers and placement of spares and repair parts), test or support equipment for all levels of maintenance, and planned support facilities.

Some systems go into operational testing without a plan for specific numbers of spares or repair parts. This situation becomes a test limitation. The problem is due in large part to cost and manufacturing constraints imposed either on or by the developer. In those cases, the contractor provides a portion of the required system support package.

PARAMETERS

Logistics supportability is most often evaluated in a qualitative manner, although there may be quantitative factors that are used in some of the elements of supportability. For example, supply support might be assessed by examining parameters such as percent of items in local supply assets, fill rates, etc. These parameters are then judged qualitatively to arrive at the assessment of the entire subject of logistics supportability. The evaluation of supportability is intended to consider all these subordinate factors, or considerations, and provide a composite evaluation of the balance between the support that is needed and the support that is planned.

In some test programs, the area of logistics supportability also is used to cover other suitability areas (e.g., transportation, manpower supportability, documentation, or training) that are not significant enough for a particular system to warrant an individual test objective.

KEY POINTS

Early ILS planning can be assessed as part of logistics supportability evaluation.

Early activities in Integrated Logistics Support (ILS) planning may begin before Milestone I. Some aspects of Logistics Support Analysis (LSA) also are conducted in this time frame. Review of the products of these activities may be key to any early operational assessment of operational suitability. These early activities also will give some information on the criticality of the support aspects of the system. If the system is to have a unique support concept that will succeed only under certain system reliability and maintainability levels, then this might be identified as an operational suitability critical operational issue (COI). Such an examination will begin to focus on the critical aspects of the suitability that need to be addressed in the OT&E

planning. One example of potential support problems is a system that is intended to support a number of different weapon systems – within the context of one weapon system, the planning may be accurate, but for others or for the total support requirement, the planning may not be correct.

ILS planning can provide the basis to assess the planned logistics support.

An early assessment of logistics supportability can be made by reviewing the status of the logistics support planning. One portion of this activity should be a review of the Integrated Logistics Support Plan (ILSP), or of the results of the logistics support analysis. How complete and well done the planning is done determines to a large degree how acceptable the support of the system will be. Modeling and simulation (see section 2.1) also may be used to analyze the ability of the system to meet some of its suitability requirements with the planned level of support.

Test planning must address the support for the items under test.

As the operational test is planned, the support assets (e.g., spares, test equipment, support equipment) must be identified in the TEMP and in the detailed test plan and must be in place for the conduct of the operational test. If these support assets are not available, it will be more difficult to assess the operational suitability of the system, and it will be impossible to evaluate the performance of the support items.

Operational test data should be compared to the ILS planning factors.

Assessment of the ILS planning should continue as part of the OTA's activity to support the OT&E report for the Milestone III decision. Operational test data should be compared to the ILS planning factors and evaluated to determine if the planning factors reflect the real needs of the system. If the test data contain demand rates (e.g., MTBR) from the operational test period, these rates should be compared to the rates that were projected in the logistics planning. Incompatibility of the planning and the system parameters is one of the major causes of systems being unable to meet their availability requirements during the first stages of operational fielding.

Supportability of software should be considered.

For those systems that have significant software elements, the support of the system's software can be an important factor in the ability to provide logistics support for the entire system. Planning for support of software includes both manpower and equipment resources. The personnel who will be used to maintain or upgrade the software during its operational use must have adequate documentation to allow them to perform their function. Evaluations during OT&E can provide insight into the adequacy of the planning for the support of the software. (Software supportability is discussed in more detail in section 2.5.)

Supply support during operational testing may be unrealistic.

Some test programs provide an "iron mountain" of spares and repair parts to optimize the use of valuable test range times, test forces, instrumentation, etc. In these situations, the evaluation of test results must compensate for the unrealistic conditions in the logistics support of the systems under test.

1.7 TRANSPORTABILITY

Transportability is defined as

the capability of materiel to be moved by towing, self-propulsion, or carrier through any means, such as railways, highways, waterways, pipelines, oceans, and airways. (Full consideration of available and projected transportation assets, mobility plans and schedules, and the impact of system equipment and support items on the strategic mobility of operating military forces is required to achieve this capability.)

System requirements and employment methods may dictate that specific transportation modes be used for deployment purposes for some deployment scenarios. Assessment of these different modes of transportation should be accomplished by the developing agency. Other areas of attention include the need for any unusual transportation or handling equipment. The compatibility with transport aircraft, ships, or any vehicles that are essential for the system to arrive at its destination and then perform its mission also must be addressed. This compatibility includes physical dimensions and clearances, tie downs, and load capacity. Routine transportation and mobility movement of spares and support equipment also should be considered. The capability of the item to be included in any required at-sea replenishment or amphibious operations should be addressed. These elements include the ability of the system to be transported by the planned means or within the intended transportation capability of the DoD.

Transportability also may include the "deployability" of a system or equipment that is deployed with combat units to the combat area, and the "portability" of items that are carried by user personnel during use. Compatibility with the using personnel also must be assessed. Personnel who will prepare and move the item as part of its transportation must be physically capable of performing the required tasks.

PARAMETERS

Parameters associated with transportability must address the characteristics that will allow existing transportation assets to move and transport the equipment as needed to support the operational mission. If new transportation assets are planned specifically for this system, then the evaluation should address the acceptability of these new assets. Some parameters associated with transportability are:

- Does the using organization have the provisions for handling and transporting the system?

- Can the system be transported to the theater by the preferred means?

- Can the system be moved adequately within the theater of operations?

- Are the dimensions and weight within the required limits for each possible transportation mode that will be required to move the equipment?

KEY POINTS

Unique transportability requirements should be identified.

Initial system transportability requirements should be specified in the early system planning documents, and the acquisition and using agencies should assess these requirements against the capabilities of existing transportation assets. The role of OT planners is to examine these requirements and determine if test resource assets (e.g., cargo aircraft, rail cars) are needed for OT. The need for special transportability test events also should be addressed. If there is a critical transportability issue, this needs to be identified in an early TEMP.

Transportability of the system should be verified as part of operational testing.

If the system is a major rail- or air-transportable item, for example, a tank or a helicopter, the compatibility with the transporting means should be verified. Often, the DT will examine this compatibility, but from a technical standpoint, i.e., does it "fit?" While an argument can be made that the transportability requirement has been verified by this DT evaluation, there are operational factors that need consideration. Just because contractor engineers are able to load the system into the transporting aircraft on a clear day in good weather does not mean that the using troops can perform the same task under all weather and lighting conditions. In the case of manpack items, the ability of the person to carry the item may be proven, but can the person who is carrying the item still perform the assigned mission, or is there some negative impact on combat effectiveness. The OT examination is directed more at "can it be done by the normal user troops under the conditions predicted for the using organization." Operationally realistic conditions can yield results different from those produced by the DT.

All projected areas of operations should be included in the transportability assessment.

Due to weight, dimensions, and system characteristics, the transportability of the system may be limited in certain geographic areas of operation. For example, the dimensions of a tank may be compatible with U.S. rail transportation, but the use of rail transportation in other countries will be limited because rail widths and capability differ from that in the United States. Systems with extensive global commitments must be analyzed very carefully to ensure that all transportability requirements are understood and can be met. If the system has a unique transportability requirement, it should be made part of the system planning documentation and considered for examination as part of the OT.

Transportability should include the movement of the system into combat locations.

The system must be moved into and within a theater of operations consistent with its mission. This issue may deal with airplane, train, or ship loading and internal or external helicopter loads. The examination should address the ability of the transporting system to carry the load, and any impacts on maneuverability once loaded. It should ensure that the weight and dimensions of the new system can be supported by the transportation network and current bridging (to include tactical bridging) in the required operational environment.

Testing of systems after being transported can be critical for some systems.

For some systems, operational testing should be planned to verify the fact that transporting the system has not degraded its capability. Realistic scenarios of preparation for transport, the actual transport of the system, and set-up for operation all should be included in the operational testing scenario. The importance of this activity varies from system to system, and should be included in the testing requirements if the requirement is judged to be significant.

1.8 DOCUMENTATION

Documentation is a portion of technical data and information that is part of every system.

> *For the purposes of OT&E, documentation comprises operator and maintenance instructions, repair parts lists, and support manuals, as well as manuals related to computer programs and system software.*

The ability to operate and maintain new and advanced systems can be highly dependent on the completeness and accuracy of the documentation that is provided with the system. For complex systems, the operator and maintainer documentation can make the difference between success and failure of the system.

During the documentation development process, usually during the full-scale development phase, representatives of the user organizations generally will conduct a validation of the documentation. The validation process addresses the ability to locate procedures and tasks, as well as the need for any additional tasks required to support maintenance operations. Documentation clarity, accuracy, and ability to support projected skill levels also is validated. Cautions, warnings, and advisories are reviewed to ensure that they are appropriate for incorporation in the manual, and are checked to ensure that they are accurate, clear, and easily identifiable to the reader. Preventive maintenance checks, services, and procedures also are validated.

The validation process generally is accomplished in two phases. Developmental testing personnel usually perform the first phase, and determine if the drawings, figures, specifications, and procedures are technically correct. The second phase usually is done by operational testing personnel. They determine if the maintenance technician and operator can understand and correctly perform the procedures outlined in the documentation. This examination may be performed in conjunction with other suitability evaluation activities, including data collection for maintainability, training, and human factors evaluations.

In addition to any "formal" validation tasks, the documentation also should be part of the activity on other OT tasks. For example, when operations or maintenance is performed during the OT, the documentation that is used should be assessed for its completeness, accuracy, ease of use, etc. The OT&E plan should discuss how the results of these naturally occurring documentation assessments will be recorded.

PARAMETERS

Documentation evaluation is primarily qualitative in nature. There are some quantitative parameters that might contribute to organizing and managing the assessment of the documentation. Three examples follow.

Percent of Critical Tasks or Procedures Available: Clearly, the weakest documentation procedure is the one that does not exist. This parameter indicates how complete the documentation is at the time of OT. Documentation can be made available in various forms, e.g., draft, "blue line," final deliverable. The percentage of each form that is provided to the operational test activity can be a good indication of the status of the documentation development.

Percent of Critical Tasks or Procedures Validated: For the total number of tasks or procedures in the operating or maintenance manuals, this represents the percentage that have been validated. It can be applied to maintenance, operator, or other support-critical tasks or procedures, and it should approach 100 percent as the system nears the production decision.

Percent of Erroneous Procedures or Tasks: For the total number of tasks and procedures demonstrated, this is the percentage that are considered to be erroneous. Other similar parameters can be developed to highlight the number of unclear tasks, tasks that have too much detail, insufficient detail, etc. The parameters will depend on the manner of collecting this information at the operational test site.

KEY POINTS

Documentation should be available for the operational test phase.

The documentation development and assessment schedule must be compatible with scheduled operational test time frames. The early assessment of the documentation preparation program is one form of early suitability assessment. A good process, with adequate schedule and resources, may produce good documentation. A poorly scheduled program, or one with inadequate resources, probably will yield poor results. At a minimum, preliminary documents should be available for the operational testing phase, even if the final documents are not ready.

Documentation may not be available for the operational testing schedule.

While the best test of documents is to use them during OT, the delivery dates for the documentation may make it difficult to evaluate the final product during OT. The effect of any schedule shortcomings should be known well in advance and arrangements made for work-arounds, use of draft documents, or other alternative evaluations. For accelerated programs, the OTA should identify, and include in the OT&E plan, alternative methods for achieving the evaluation of this area. Delays in availability of essential technical manuals can cause a test to experience disruptive delays or, more significantly, result in an improper evaluation of the planned support system or system reliability, availability, and maintainability.

Assessment of documentation may be in a separate test phase.

The assessment of the documentation usually requires a separate documentation test phase to determine their adequacy, prior to using the documentation as part of system operational testing. This testing should stress the use of military personnel skills, tools, facilities, and support equipment that are planned for use in the support environment when the system is fielded.

Only a sample of the operation, maintenance, and support tasks in the documentation may be naturally occurring in OT.

One of the difficulties in documentation assessment is that it needs to address a relatively large percentage of the operating and maintenance tasks at the organizational and intermediate (direct support) levels, as well as a sampling of maintenance tasks at the general support level. It may be difficult to evaluate voluminous documentation when the test period is relatively short. The use of system documentation during operational testing will provide data on its acceptability in a narrow range of circumstances. One alternative is to use data from other sources, e.g., maintenance during DT and maintainability demonstrations (see section 1.3). Any critical task or procedure not observed adequately during the operational testing should be validated in a separate scheduled event.

Manpower supportability is defined as

*the identification and acquisition of military and civilian personnel with
the skills and grades required to operate and support a materiel system
over its lifetime at peacetime and wartime rates.*

Within the context of operational test and evaluation, manpower supportability takes into consideration the numbers, skill types, and skill levels of the personnel required to operate, maintain, and support the systems in both peacetime and wartime environments. Manpower supportability, therefore, is closely related to training requirements, human factors, and maintainability.

Increases, deletions, and changes to the force structure may be required to place the system in its operating units. Documents are developed which indicate the projected manpower requirements and skill codes and grades that are necessary. The OT objective here is to assess if the projected levels are adequate to operate and support the system.

The determination of the number of manpower spaces required is based on the various scenarios in which the system will be used. They depend on the system having the projected reliability and maintainability, and the support resources, diagnostics, test equipment, etc., as planned. Shortfalls in these areas can have significant impact on the required manpower. If the projected manpower is inadequate to support the system, then significant problems could occur when the system is fielded.

PARAMETERS

The general parameter for manpower supportability is the number of personnel required to man the system when it is employed. It addresses operating, maintenance, and other support personnel, and their required skills and training. Other parameters that might be used include the following three:

Crew Size: The number of people required to operate the system and perform the tasks required in each speciality and at each skill level, and to use the system in the intended scenario(s).

Maintenance Ratio: The ratio of maintenance manhours per operating hour or life unit (see section 1.3). This measure allows the comparison of the projected maintenance workload and the workload demonstrated during operational testing. On- and off-system Maintenance Ratios (MRs) are estimated for each level of maintenance and for each skill code. MR criteria typically are found in the requirements document.

Current Crew Size and Maintenance Ratio: A comparison of the system's manpower requirements with those of the current system can provide a meaningful measure of the criticality of the manpower supportability.

KEY POINTS

Manpower supportability includes examination of the operating crew.

While manpower supportability may highlight the support aspects of manpower (e.g., maintenance crews and skills), the operating crew is an important part of the evaluation. The OT&E test plan always should indicate that the operating crew size, skills, etc., will be part of the evaluation.

Manpower deficiencies actually may reside in other suitability areas.

On some systems, it may appear that the manpower estimated is inadequate to operate or maintain the system. If the system is experiencing shortfalls in expected reliability, maintainability, or diagnostics, or has human factors problems, then the deficiency may be more correctly assigned to these areas.

Manpower planning for OT&E should not include "Golden Crews."

The personnel who man and maintain the systems during the operational testing should not be of such a high skill level that the test results are invalid. The thrust of OT&E is to see if the system is suitable in the hands of "troops" who are representative of the intended operational users. Realism also may be lost if the personnel in the testing organization have received a greater number of exposures to the tasks than will be the case with the planned user personnel. An example would be the use of hand-held ground-to-air missiles -- if the intended users will never have the opportunity to fire a live round during their training, but only have exposure to simulators, then it is unrealistic to use personnel in the OT who have had experience with a number of firings during DT, or other testing of this system, or similar systems.

Skill levels and numbers may be hard to evaluate.

The complement of personnel that is used during some operational tests may have somewhat higher skill levels than are planned for the operational units. These higher skill levels are justified by the OTA as necessary because it takes higher skill level personnel to recognize deficiencies in the system. In this situation, the evaluation of the manpower resources needed to operate and maintain the system must consider the skills that were present during testing. The OT&E plan must include an adequate evaluation procedure.

Proper manning levels for systems are critical for efficient operations.

The OTA must carefully evaluate the manning levels of units who will field new systems. Improperly manned equipment will result in poorly operated and maintained systems. During the fielding of one system, it was discovered that the system was not properly manned; additional personnel were required to allow units in the field to be more self sufficient. On another major system, the proposed maintenance organizations did not have personnel or a supporting organization to maintain the required radio frequency signal management system. This lack of manpower would have resulted in those maintenance tasks being transferred to a higher maintenance level, thereby reducing the efficiency of the unit.

1.10 TRAINING REQUIREMENTS

Training and Training Support are defined as

the processes, procedures, techniques, training devices, and equipment used to train civilian and active duty and reserve military personnel to operate and support a materiel system. This includes individual and crew training; new equipment training; initial, formal, and on-the-job training; and logistic support planning for training equipment and training device acquisitions and installations.

During the OT&E, the planned training program, along with any training devices and equipment, should be evaluated. The training program and supporting materials are developed during various phases of the weapon system development process. The supporting materials include programs of instruction, on-the-job training documentation, training materials, and, when required, training aids and simulators. Training materials are provided for both individual operator and maintainer training, as well as for "collective" training for crews or units.

Operators are trained to perform all critical tasks required to operate the system. Maintenance personnel are trained to perform all critical tasks required to maintain the system. Collective training is provided to system crews whose members are required to perform as a team. All tasks must be accomplished to prescribed training standards. If tasks to be performed are linked to or dependent on other tasks (e.g., firing sequence, or an initialization sequence), all tasks must be performed to standard in a single performance test.

Evaluation of training should address the effectiveness of the training program in providing personnel who can operate and maintain the system. Maintenance training must be analyzed from the organizational through the intermediate level and include the training program, as well as training aids, simulators, and support equipment used at each of the levels of maintenance. Particular attention always should be given to performance of critical tasks. In addition, tasks that are new, unique, or hazardous must be included in the evaluation, or some assurance should be given that these tasks can be performed satisfactorily.

A training deficiency exists when the training provided does not address the skills needed to operate or maintain the system. Once a deficiency has been identified, an assessment should be made that classifies the deficiency as a shortcoming in the training provided, in the documentation, or in the system itself.

PARAMETERS

Training effectiveness is based on both the training programs and the performance of the individuals while accomplishing tasks associated with the use, operation, and support of the system, to include individual and collective training.

The operational evaluation addresses how well the trained individuals perform the required tasks. The ability to perform the necessary tasks correctly, once the individual(s) is in an operating environment, establishes that the system can be operated and maintained by the personnel so trained. However, criteria also are needed for operator and maintainer performance during combat. These criteria may not be the same as those used during peacetime. For example, changing a tank engine in a maintenance bay is much different from changing the engine in the field, at night, and under rainy conditions.

The parameter "critical tasks demonstrated" is the ratio of critical tasks demonstrated by the trainee using validated procedures within the time standard, to the total number of tasks attempted, or total tasks within the manuals. It can be calculated for each maintenance level or for each skill category (MOS, AFSC, etc.). This parameter has a close alignment with some of the parameters used in the evaluation of documentation (see section 1.8).

KEY POINTS

OT experience can be used to modify the training requirements.

During OT&E, operators and maintenance personnel gain experience with the system and task procedures and skills required to operate and maintain the system. This experience may indicate required changes to the training and skill needs. The evaluation report should indicate if training and skill needs should be changed. Along with these changes, training aids, simulators, and support equipment must be assessed to ensure that they are adequate to support the operational requirements.

OT planning must address when the training program will be available for evaluation.

The delivery of all required training materials and equipment may not coincide with the OT&E schedule. Training manuals usually are not developed on schedule, or they are in an early draft stage. Further, software changes just prior to test may cause major changes in system operations, or personnel available to the test program may have training that is not representative of that planned for the operating units. Unless OT planning considers these possibilities, the OT&E may be unable to evaluate the training program.

The interrelationship between training, documentation (section 1.8), and human factors (section 1.13) must be recognized during the OT planning.

Just as the documentation evaluation is directed at examining various important operating and maintenance tasks, the ability of the personnel to perform the tasks with the documentation provided is dependent on the training those personnel have received. Similarly, human factors and training are related. Tasks that incorporate unusual or complex human factor aspects may require additional or more extensive training. Combined evaluation of these areas may prove to be very beneficial and should be considered during the planning for the OT&E. The adequacy of the training for very complex or demanding tasks should be assessed by reviewing the personnel performance during the actual system operation.

Training and OT tasks should be correlated.

The correlations between the tasks included in the training and the tasks performed during the operational test should be analyzed. Tasks should be identified where the personnel either were not trained or were inadequately trained. There also may be tasks where training was determined to be unnecessary.

Any awkward or unusually demanding tasks that caused personnel problems should be identified.

In some instances, the training requirements and the training planned are based upon an inaccurate view of the system's operations or maintenance activities. OT can identify unusually critical tasks that need to have the training re-evaluated. This activity is closely related to human factors (section 1.13).

Wartime usage rates for a system is defined as

the quantitative statement of the projected manner in which the system is to be used in its intended wartime environment.

Wartime usage rates can be expressed in parameters such as flying hours per month, miles per day, rounds per day, or hours per month. The full meaning of these parameters requires a definition of the rate in relation to the planned operational scenario. For example, miles per day has limited meaning unless the "miles" are characterized by speed, terrain, system activity, etc. Similarly, sorties per day is not a valid measure unless the characteristics of the sortie are defined, e.g., mission, weapons carried, sortie length, speed.

The addition of "wartime usage rates" into the list of suitability issues resulted from a concern that, in some instances, the suitability of systems was being assessed at an unrealistic tempo during the operational testing period. Wartime usage rates was added to emphasize the need to have suitability evaluations conducted at usage rates that approximate those anticipated during wartime use. Within these frequency measures, there also needs to be a description of the missions themselves, including mission duration. Early in the system's development, these mission profiles must be identified by the acquisition organization in conjunction with the using and supporting organizations. As the system progresses through the development cycle, it becomes more and more important that the usage rates be defined in greater detail. The design must be made in the context of this usage rate, and the logistics support must be planned in consideration of these rates. When OT&E is planned and conducted, the wartime usage rates are a fundamental part of determining how to structure a test to determine if the system can meet its wartime demands.

All of the operational suitability areas contribute to the ability of the system to realize the wartime rates of usage. The number of flying hours, miles, or rounds that the system is capable of providing is dependent on its availability and the balance between the logistics demands and the logistics resources that are provided.

PARAMETERS

To assess the ability of the planned logistics system to support a new weapon system requires that the logistics support be examined in the context of the projected wartime usage rates. When a need is postulated, there may not be an accurate projection of what the wartime usage rate is. These parameters must be identified in the requirements documentation. Example measures are sorties per day for a tactical aircraft, hours per day for simulators and some communications systems, message units per time period for other communications systems, rounds per day for ground combat systems, etc.

KEY POINTS

The usage parameters should be identified early in the program's development.

The parameters or measures for wartime usage should be known and agreed to among the participants in the development process at Milestone I. Usually the parameters for certain classes of systems are relatively easy to specify and to reach agreement on. Examples might be

miles per day for a tank or ground vehicle, flying hours per month or sorties per day for aircraft, hours per month for surveillance systems, or rounds per day for an artillery piece.

Usage parameters must be fully defined.

The wartime usage rate must have full definition of the wartime mission or scenario for the rate to have meaning. Message rate per day may be an acceptable usage rate for a communications system, but the content and complexity of the messages must be defined to give the statement meaning. These definitions can be a composite of types, i.e., "x" percent of these message, "y" percent of those, etc. These defined usage rates will be documented in the Operational Mode Summary, Mission Profile, or similar documents.

Usage rates should be developed with the new system's capabilities in mind.

If the system's usage rates are based upon predecessor systems' experience, these rates should be analyzed by the intended users to assure that they still are valid. In many cases, new systems with improved capabilities have been found to have very different use patterns once they are placed with the operating units. Examples are surveillance systems that were used infrequently until they were replaced by higher capability systems. The using organizations were so pleased with the improved systems that the usage increased significantly to almost continuous use.

The operating tempo during OT should be developed from the planned usage rates.

By Milestone II, the value for the wartime usage rates should be known and documented in an Operational Mode Summary, or similar document. These rates also should be included in the Milestone II TEMP, by reference. The developing agencies should understand the usage rates. They also should be used by the agencies performing the logistics planning, and should be part of the requirements used in the planning of the OT&E program.

The OT may be incapable of directly demonstrating the wartime usage rates.

The planned OT should test the wartime usage as specified in the Operational Mode Summary, or mission profile. Any attempt to avoid testing under typical combat conditions/wartime usage rates should be examined carefully, as such unrealistic operation could significantly alter the suitability performance seen during testing and serve as a severe test limitation. If the planned OT is incapable of testing the system at the high level of wartime usage, then modeling and simulation should be used to project the system's capability at rates higher than those seen during the operational testing. This modeling and simulation requirement should be identified by the OTA in the Milestone II TEMP, and planning initiated to develop and validate the required models and simulations.

Some evaluation must be made of the system's capability to perform at the planned wartime usage rates.

The capability of the system to perform at wartime usage rates should be assessed in the OT&E prior to Milestone III, or IIIA if there is one. If there is doubt about the ability of the logistics system to support the system at this rate or the ability of the system to perform at this rate, then the test report should highlight these conclusions. If there is a perceived limitation on the system usage rate, this limitation should be highlighted in the OT&E report. As an example, an aircraft system was incapable of achieving its squadron level sortie rate because of the demand placed on the second level test equipment and the number of test stations planned for each squadron. The highlighting of this deficiency resulted in a re-evaluation of the number of test stations.

1.12 SAFETY

Safety is defined as

freedom from those conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment.

Safety is an essential and integral part of assessing a system in an operational environment. It addresses any potential hazards that the system (both hardware and software) poses to personnel, or other systems or equipment. Safety usually is evaluated by observing the system's use and maintenance while performing other portions of the operational testing. Because the safety assessment is a byproduct of this testing, it is important to ensure that safety aspects of the system's use are not overlooked as the principal attention is focused on other aspects of the system's testing. Since the OT&E may be the first instance where the system will be operated and used in its planned environment, this also may be the first instance where it will be possible to observe any potential safety problems.

The acquisition organization usually will conduct system safety programs on more complex systems. The system safety program uses engineering and management techniques to identify and eliminate potential hazards and reduce associated risks.

PARAMETERS

During some operational tests, the OTA may use the categories and hazard levels from the system safety program as a way of identifying the results of the OT from a safety standpoint. The parameters for system safety relate to the number of hazards in specified categories and the projected frequency of exposure to these classes of hazards.

Number of Hazards by Category: MIL-STD-882 has a series of four hazard categories, with Category I, Catastrophic, being the most serious. The categories are:

Description	Category	Mishap Definition
Catastrophic	I	Death, or system loss
Critical	II	Severe injury, severe occupational illness, or major system damage
Marginal	III	Minor injury, minor occupational illness, or minor system damage
Negligible	IV	Less than minor injury, occupational illness, or system damage

For most systems, the objective is to eliminate all Category I and II hazards. Also, the hazards that are identified during operational testing should be categorized, if possible.

Hazard Probability: If possible, any observed hazards should be identified by the probability levels that are used in system safety programs. This designation may aid in the investigation and resolution of the hazards. The hazard probability levels (contained in MIL-STD-882) are:

Level	Probability	Definition
A	Frequent	Likely to occur frequently
B	Probable	Will occur several times in the life of the item
C	Occasional	Likely to occur sometime in life of an item
D	Remote	Unlikely, but possible to occur in life of an item
E	Improbable	So unlikely that it can be assumed occurrence may not be experienced

KEY POINTS

Operational testing provides an opportunity to observe the system operated and supported by personnel having the expected skill levels.

Prior to operational testing, the personnel who operate and maintain the system probably will have higher skill and experience levels than will the planned operational personnel. Therefore, the OT is the first opportunity to observe the system in the hands of personnel with the projected levels of experience and skills. This first observation may indicate potential safety problems that were not observed in the earlier testing. Test planning should focus attention on detecting and documenting any new or unexpected hazards to personnel. This observation is closely related to human factors assessment (see section 1.13).

Observers of operational tests should be sensitive to any potential for significant hazards.

All personnel who are involved in or associated with the conduct of the operational testing have a responsibility to identify any potential hazard, and cause the test to be stopped if a hazard in Categories I or II is perceived. In most cases, operational testing should be conducted without outside interference, but safety is an exception.

Safety testing should consider the operating environment of the system.

Any safety-oriented testing or assessment should consider the entire expected range of environments. Some safety features may be very effective in good weather on a clear day. Hazards may be clearly seen and easily avoided. In poor lighting or in bad weather, poor visibility may result in unexpected hazardous conditions.

Software faults can result in unexpected hazards.

Faults observed in the software should be evaluated for potential contribution to hazardous conditions. As an example, for aircraft systems, software faults can impact flight safety.

1.13 HUMAN FACTORS

Human Factors is defined as

*those elements of system operation and maintenance which influence
the efficiency with which people can use systems to accomplish the op-
erational mission. The important elements of human factors are the
equipment (e.g., arrangement of controls and displays), the work envi-
ronment (e.g., room layout, noise level, temperature, lighting, etc.), the
task (e.g., length and complexity of operating procedures), and person-
nel (e.g., capabilities of operators and maintainers).*

This suitability element addresses the compatibility among system hardware and software
elements and the human elements. It is intended to identify system performance problems,
human task performance problems, and hazards to personnel under realistic conditions of combat
use. While there is a close alliance between the human factors examination and the examination
of manpower supportability (see section 1.9), training (see section 1.10), and safety (see section
1.12), human factors is focused more on the hardware and software elements of the system. It is
more of an evaluation of the system itself, what the system requires of the people who operate
and maintain it, and how the system fits into the relationship with the people who are going to
operate and maintain it.

Evaluation of the human factors aspects of a new system includes all of the interfaces between
personnel and the hardware and software. It also includes the interfaces with both the system
operators and the system maintenance personnel.

The human factors considerations include compatibility of the man-machine interface.
Considerations in this area comprise information displays (machine feedback), symbology
(standard versus unique), operator controls, personnel comfort and convenience, portability of
the equipment (bulk, weight, load distribution, straps, handles, etc.), accessibility for operation
and maintenance, physical workload demands, mental workload/information processing
demands, compatibility with task characteristics, task environment, etc.

Traditional human factors testing also may address ergonomic (e.g., can the operator see or reach
the indicator or control) considerations, although this area normally is part of the developmental
testing. The OT&E should address the operator's effectiveness and efficiency in the performance
of assigned tasks.

PARAMETERS

Human factors is evaluated qualitatively using checklists that focus attention on the human fac-
tors aspects of the system. It also can be evaluated quantitatively by performing timed tasks.
Data to assist in the evaluation may be collected on task times, response times, error rates, accu-
racy, etc. Interviews, questionnaires, and debriefings of operators and maintenance personnel
can be used to gather data on impressions of displays, man-machine interface, accessibility, port-
ability, task environment, task difficulty, unnecessary steps, work space, personnel fatigue, etc.

KEY POINTS

Human factors should address both operators and maintenance personnel.

Human factors evaluation should address the ability of the operators to use and to control the functioning of the system. It also should ensure that the support personnel have the access and the physical capability to perform the required maintenance.

The software interface with personnel should be assessed.

As systems become more software intensive, there is a need to evaluate the interface of the software with the operators and/or maintenance personnel. How does the software present information? Is it clear, or can there be misinterpretation? Is there consistency among the various software displays so the operators will have an acceptable learning curve as the system is used? Is software designed with safeguards, to the extent possible, against system failures due to incorrect key entries? Some OTAs use checklists and questionnaires to examine the "usability" of the software.

Physical demands on personnel should be assessed.

Consideration needs to be given to the manner in which the system is to be used under combat conditions. Are the personnel likely to be operating or maintaining the system while wearing protective clothing against the weather or against chemical, nuclear, or biological attack? How long will they have to operate under these conditions for the system to perform its mission(s)? Does the system require relatively long periods of concentration, or exertion? Some soldier-fired systems require the sights to be kept on the target for a long period of time. Is this period realistic in terms of human capability for the average person?

The employment of new or advanced display techniques should be identified.

When new or advanced display techniques are used in the operator's station or in maintenance equipment, there may be significant questions about how these changes will be accepted and integrated into the operation of the line operating unit. A COI should be identified and the OT should ensure that any potential problems are examined in adequate detail.

Human factor conditions should consider the entire operating environment.

The examination of the man-machine interface needs to consider that the system will be operated under a wide rage of conditions. If needed, can the system be used effectively with arctic clothing, CBR protective clothing, etc.? Can it be effectively used in poor weather, or with limited lighting? In one example, the OTA took user troops to the contractor's facility where they found that the systems could not be assembled by the planned field personnel. They also discovered that tactical personnel could not enter some of the shelters with packs and weapons, forcing them to leave these items outside in potentially hostile or contaminated environments.

Combat stress conditions can affect the ability of personnel to operate or maintain the system, and should be evaluated.

Concerns for the ability of personnel to use and repair the system under combat stress conditions must be addressed. Under very stressful conditions, often only the simplest tasks succeed. Simulating the combat stress factor is very difficult. The number and frequency of different tasks should be analyzed and documented in the operational test plan. The plan should include the measures that will be used to gain insight into the reactions of the people to the stress of the proposed environment, and their ability to perform as required.

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Chapter 2
OTHER OPERATIONAL SUITABILITY ISSUES

In addition to the suitability elements that are enumerated in the definition of operational suitability and are discussed in Chapter 1, there are additional topics that are essential to a discussion of operational suitability in OT&E. These topics need emphasis and understanding for operational suitability to be effectively evaluated during OT&E. Among these topics are suitability modeling and simulation, integrated diagnostics, environmental factors, electromagnetic environmental effects (E3), and software supportability. The following sections discuss these topics.

2.1 SUITABILITY MODELING AND SIMULATION

The DoD is in the process of issuing expanded guidance on the development, validation, and use of modeling and simulation (M&S) in the acquisition process. In January 1989, the Director of Operational Test and Evaluation (DOT&E) issued the "DOT&E Policy for the Application of Modeling and Simulation in Support of Operational Test and Evaluation."

A model is defined as

a representation of an actual or conceptual system that involves mathematics, logical expressions, or computer simulations that can be used to predict how the system might perform or survive under various conditions or in a range of hostile environments.

Simulation is defined as

a method for implementing a model. It is the process of conducting experiments with a model for the purpose of understanding the behavior of the system modeled under selected conditions or of evaluating various strategies for the operation of the system within the limits imposed by developmental or operational criteria.

There are several different types of simulations, including those that use analog or digital devices, laboratory models, or "test-bed" sites.

The use of properly validated M&S is strongly encouraged during the early phases of a program to assess those areas that cannot be directly observed through testing. The use of M&S is not a substitute for actual testing; however, it can provide early projections and reduce test costs by supplementing actual test data.

The use of modeling and simulation in the operational suitability area can provide a number of benefits. M&S can be used to focus limited test resources by identifying the critical elements in a logistics support system, e.g., the choke points for the flow of the support resources. M&S also can be used to translate the rate of use in the test scenario to the wartime usage rate. If, for example, test aircraft are flying only one or two sorties per day, the "load" on the support resources is significantly different than if a higher, wartime sortie rate was being flown. M&S can aid in assessing the impact of these differences. M&S also may be used to evaluate elements of the support system that are not present at the test site. For example, if the second-level maintenance capability (test equipment, facilities, etc.) is not available, then a properly constructed and validated model can be used to provide insight into the ability of the planned second-level maintenance facility to support the system.

PARAMETERS

The key parameters in M&S are the assumptions and ground rules used in inputting data. The output can only be valid if valid assumptions and ground rules have been used.

KEY POINTS

Plans for M&S should be evaluated for potential credibility of the results.

The credibility of the results of M&S is a judgment formed from the composite of impressions of the inputs, processes, outputs, conclusions, the persons or agencies involved, and the strength of the evidence presented. Appendix B of the "DOT&E Policy for the Application of Modeling and Simulation in Support of Operational Test and Evaluation" provides a series of questions to assist in assessing M&S results' credibility. These questions provide a good outline for examining M&S activities.

All of the models planned for use on the OT&E program should be accredited for the purpose.

Accreditation is defined as the process of certifying that a computer model has achieved an established standard such that it can be applied for a specific purpose. This means that management has examined the model and based upon experience and expert judgment, has declared that the model is adequate for its intended use.

Detailed definitions of planned operating and support scenarios are essential for a valid M&S effort.

In many cases, the detailed definition that is needed for M&S is beyond that existing in program documentation. This is particularly true in the suitability area, where the maintenance and supply concepts to be used must be defined in detail. There is a potential for the M&S results to be driven by some of the necessary assumptions rather than by the system characteristics. On the other hand, if the responsible personnel and organizations are requested to provide the required detail, and the support planning is thought through, then other organizations within the program also will benefit.

The latest program information must be incorporated into the M&S activity.

Many modeling efforts lack current information. Program conditions may change. The system design may be revised, or new threat information received. In each case, the earlier model may be invalidated. Assuring that the modeling results reflect the best and most current information available is an important consideration. Procedures must be established to assure that current information is provided to those doing the modeling and evaluation of the simulation results.

Defined plans for the use of M&S should be presented in the TEMP.

The TEMP should indicate any plans for the use of suitability modeling and simulation to complement or supplement the operational testing. The models to be used should be identified, and plans for their validation described. M&S should not be used in place of actual testing.

The TEMP and other test documentation should include a discussion of the rationale for the selection of the specific models that are planned for suitability analysis.

Models are used for many of the assessments for suitability. The Services should list the models and discuss their advantages/disadvantages in the TEMP or other test documentation so that an evaluation can be made as to the utility of the model. The DOT&E evaluator must be able to assess the validity of the selected models and of the OTA's assessment results from the model's use.

2.2 INTEGRATED DIAGNOSTICS

Diagnostics is defined in the OTAs Multi-Service Testing MOA as

the ability of integrated diagnostics (automated, semi-automated, and manual techniques taken as a whole) to fault-detect and fault-isolate in a timely manner.

Integrated Diagnostics is defined as

a structured process, which maximizes the effectiveness of diagnostics by integrating pertinent elements, such as testability, automatic and manual testing, training, maintenance aiding, and technical information that will satisfy weapon system peacetime and combat mission requirements and enable critical failures to be fixed with minimum loss of operational availability.

The purpose of integrated diagnostics is to provide a cost-effective capability to detect and unambiguously isolate all faults known or expected to occur in weapons systems and equipment in order to satisfy weapon system mission requirements. In wartime, this becomes extremely significant in that it is imperative that critical failures be found and fixed quickly to support combat turn-around times, which can equalize battles against numerically superior forces

The term "Diagnostics" often is used as a general term to cover all means of determining that a system fault has occurred, and the means to determine where the fault is and to isolate it to a portion of the system that can be repaired or replaced. There are many other terms that are used in this area, including Built-In Test (BIT), Built-In Test Equipment (BITE), Built-In Test and Fault Isolation Test (BIT/FIT), and Automatic Test Equipment (ATE).

The key to integrated diagnostics is the successful consideration and integration of the functions of detection, isolation, verification, recovery, recording, and reporting, in a comprehensive and cohesive fashion, with the operator and with support functions that may be automatically, semiautomatically and/or manually controlled.

PARAMETERS

Two parameters are listed in the OTAs MOA for diagnostics use in multi-Service OT&E test programs. They are:

Percent of Correct Detection given that a fault has occurred (P_{cd}),

$$P_{cd} = \frac{\text{The number of correct detections}}{\text{The total number of confirmed faults}}$$

Mean Time to Fault Locate (MTTFL),

$$MTTFL = \frac{\text{The amount of time required to locate faults}}{\text{The total number of faults}}$$

These parameters apply to a specified level of maintenance and therefore may be applicable to each level of maintenance.

The ability of an automated diagnostics system to isolate faults also may be measured. One parameter for this characteristics is percent fault isolation.

$$\text{Percent Fault Isolation} = \frac{\text{Number of fault isolations in which automated diagnostics effectively contributed}}{\text{Number of confirmed failures detected via all methods}} \times 100$$

Another important measure of the capability of the diagnostics system is to identify how frequently the automated diagnostics indicates that a fault exists when in fact the system is functional. This area is particularly troublesome, since the system false alarms may be either improper indications of faults that do not exist, or faults that did exist but were transient in nature. Identifying which situation exists is most difficult for complex systems. One of the more common parameters for false alarms measurement is BIT false alarm rate (expressed as a percentage).

$$\text{Percent BIT False Alarm} = \frac{\text{Number of BIT indications not resulting in maintenance actions}}{\text{Total number of BIT indications}} \times 100$$

Another important aspect of integrated diagnostics is the compatibility of the various levels of testing. The faults that are detected by the automatic built-in test must be verified by a more thorough diagnostics system than is available to maintenance personnel. The verification of a fault after removal of the equipment from the system platform is sometimes exasperating because the maintenance test station cannot duplicate the operational environment (vibration, temperature, etc.) that was present in the instance of the initial fault reporting. Once the failed item is removed, the test equipment at the next level of maintenance must be able to identify the same fault. Two parameters are commonly used in this area: the "cannot duplicate" (CND) rate and the "retest okay" rate. Both are expressed as a percentage.

$$\text{Percent Cannot Duplicate} = \frac{\text{Number of faults that could not be duplicated by later maintenance actions}}{\text{Total number of faults reported}} \times 100$$

$$\text{Percent Retest Okay} = \frac{\text{Number of faults that could not be duplicated at the next level of maintenance}}{\text{Total number of faults reported}} \times 100$$

These last three equations are based on a percentage of BIT indications. Improved parameters, used on some new systems, use a measure of life units (hours, miles, sorties) in the denominator. This results in parameters such as number of BIT false alarms per sortie or per hour.

In addition to the parameters discussed here, each of the Services employs numerous other general and unique parameters in their respective programs. These include parameters that relate to the manual, as well as automatic and semi-automatic aspects of integrated diagnostics.

KEY POINTS

The approach to system diagnostics should be discussed in the early system planning documents.

These discussions provide a basis for relating the diagnostics requirements to other system parameters such as reliability, maintainability, and availability.

All aspects of the integrated diagnostics function must be planned for.

All integrated diagnostics test items required in the support of the weapon system must be planned for. Focusing on the exotic on-board built-in test features can lead to only minimal planning for the less exotic support functions such as automatic test equipment, test program sets, technical manuals, training, and required skill levels of personnel.

The program manager should have firm diagnostics requirements established before Milestone II.

Diagnostics requirements should be the result of analysis that allocates the diagnostics requirements across the various alternatives, i.e., automated systems, semi-automated systems, test equipment, and manual troubleshooting. The initial operational testing should provide insight into the system's capability versus these allocated levels of diagnostics. The total diagnostics capability may meet the threshold, but if some elements are far from what is required, the system still may be not suitable.

Diagnostics short-falls should be evaluated by the OTA as to the total impact on the system and its support resources.

When operational test results are presented at the Milestone III decision, the evaluation of diagnostics capability should discuss the relative effect of the diagnostics performance on the reliability, maintainability, and availability of the system. For example, what is the impact on the system availability if the P_{cd} is less than the threshold?

Diagnostics short-falls may be obscured by activities in other suitability areas.

While many current systems have failed to realize the level of required diagnostics, these deficiencies have not always been corrected prior to the system being fielded, but have been offset by changes in other parts of the support system. For example, the inability of automated systems to perform the level of fault isolation that was expected may lead to an expanded use of manual troubleshooting on some portion of the system. The allocation of the diagnostic task to the various alternative methods must be assessed as part of OT&E. If the allocation cannot be realized, then the impact of a reallocation must be assessed, along with the penalties in cost or readiness that an adjustment of the allocation conveys.

Indications of poor performance of the system on-board diagnostics early in the program should be followed closely, as lack of diagnostics performance can lead to major suitability problems.

Failure of a system to perform the planned-for on-board diagnostics can have serious impacts on the support structure. If it becomes necessary to perform those functions off-platform, adequate types and quantities of support equipment may not be planned for and the planned training and personnel skill levels may not be able to absorb the required additional burden.

A common problem with diagnostics is its immaturity at the early stages of operational testing.

When the system is tested in its early stages, the diagnostics may be less capable than desired, or result in numerous false fault indications. Resulting deficiencies are labeled as the result of immaturity and, more often than not, it is projected that the mature system will not have these problems. The maturing of a diagnostics system is a difficult and demanding task. Revising the diagnostics approach to a system design that is fairly fixed generally will not yield significant improvement. The expectation of significant improvement must be accompanied by a maturation program that has the proper resources to do the job and the operational testing to verify the results.

The automated diagnostics capability of a system usually improves as the system's design matures.

The automated diagnostics capability of a system is one of the system features that usually is not completed with the initial design. The testing and operation of the system provides additional insights into both the system's performance and the potential failure modes and effects. Such information that results from development activities should be used to improve the diagnostics capability. The impact of this situation on OT&E is that the maturity of the diagnostics at the time of operational testing needs to be evaluated prior to the testing, and the test results need to be evaluated in light of system maturity.

Poor diagnostics performance can have serious effects on the system's suitability.

If the system has poor diagnostics performance during operational testing, the impact may be felt in a number of areas. The operators and maintenance personnel may loose confidence in the diagnostics system. If incorrect system status is frequently displayed to the operators, they will be unable to rely on the system displays (this can be a particular problem with protection systems, such as electronic warfare systems). Similarly, if the maintenance personnel perceive that the automatic diagnostics system is not accurate much of the time, they will have to resort to other means to maintain the system. This may result in unrealistic data from the OT or unnecessary demands being placed on the supply system, or it may cause addition requirements in documentation, training, or other logistics areas for the operational system.

2.3 ENVIRONMENTAL FACTORS

The "operational environment" is a critical factor to the operational suitability of a system. The ability of the DoD operational testing organizations to determine the operational suitability during OT&E is dependent on how the test environment compares to the operating environment. The "operational environment" is composed of many individual, distinct and almost unrelated areas. Often, each area must be addressed separately to ensure adequate, deliberate consideration.

In the context of this guide, the definition of "environment" maintains a broad scope and includes the weather: vegetation; terrain (land or water); acoustic; electrical/electronic; illumination; chemical, biological, radiation (CBR); and battlefield conditions. There are two major categories of environment; natural and man-made.

The framework for discussing environments is shown in Table 2-1.

Any environmental condition may have an impact on the system's performance and the ability to properly use the system in the intended combat or wartime environments. The word "environment" also may be modified by an appropriate explanatory adjective, e.g., combat environment, human environment, vibrational (mechanical) environment, and so forth. Taken together, these encompass what might be considered the "operational environment." Care must be exercised in the preparation of OT&E documents to ensure that the writer and the reader similarly interpret the discussion of environment.

When an operational need is stated for a new system, it is necessary to state what the conditions for use will be. These use conditions include the environmental factors that bear on the utility of the system. Any system limitation that is postulated due to environmental factors or conditions should be identified by the user or user representatives who are responsible for developing the system level requirements. These limitations also should be identified for examination as part of the OT&E. The OT&E should be planned in such a manner so as to determine if the level of limitation is as expected, or if it is more severe than estimated. Testing also should determine if the limitation affects the system in a manner other than what was predicted.

The operational requirement should state the general operating environment and indicate if the requirement includes any limitation to operational use due to the environment. That is, does the system comprise elements that are sensitive to environmental conditions (e.g., rain, fog) and also battlefield conditions (e.g., smoke, dust)?

Table 2-1 A Framework for Discussing Environments

ENVIRONMENT		NATURAL (EXAMPLES)	MAN-MADE (EXAMPLES)
WEATHER		Rain, Snow, Winds, Sea State, Fog	――
VEGETATION		Grass, Shrubs, Trees	――
TERRAIN		Swamp, Desert, Mountains, Ice, Plains, Water, Soil	* Moats, Fox Holes, Tank Traps, Roads, Urban Features
ACOUSTIC		Thunder, Rain, Fish, Whales, Waves	* Decoys, Ships
ELECTRICAL/ ELECTRONIC		Lightning, Solar Flares, Ionospheric Disturbances	* Jamming, EMP
ILLUMINATION		Sun, Moon, Eclipse	* Flares, Searchlights
CBR		Space Radiation, Epidemics	* Nuclear Radiation, Germ Warfare, Toxic Gases
B A T T L E F I E L D	SMOKE	Vegetation Fires	Target Hits
	DUST	Dust Storm	Bomb Blast
	DIRT, SAND	Sand Storm	Bomb Blast
	OBSCURANTS	Clouds, Rain, Fog, Snow, Haze, Sand, Dust	* Smoke Canisters, Flares, Battle Dust and Debris

* Enemy actions or countermeasures that impact on survivability or susceptibility are evaluated as components of operational effectiveness and are not addressed under operational suitability.

PARAMETERS

Environmental parameters can be used to characterize the intended use environment, e.g., terrain that the system is intended to travel over, or they can be used to characterize the system's capability versus the environment, e.g., minimum visibility level at which the seeker will be capable of operating. The first category is used to communicate the user's environmental requirements, while the second communicates the system's capability within the environment. Examples of parameters that communicate the environment are:

Terrain Grade:	The incline a ground vehicle should be able climb, given its power and traction
Water Depth:	The water level through which a ground vehicle should be able to pass
Sea State:	Ocean wave conditions under which a vessel should be able to perform certain mission functions.

Examples of parameters that communicate the system's capability within an environment are:

Range:	The detection range of a seeker under certain specified obscurant conditions
Speed:	Vehicle speed over specified terrain conditions.

KEY POINTS

Most systems have environmental limitations.

These limitations are defined as the degree of conditions (e.g., weather, sea state) under which the system will not be able to operate effectively. That a system will not be able to perform in extreme adverse conditions is an accepted fact for most systems, but the threshold for non-effectiveness must be known to the user.

Environmental limitations should be quantified and understood.

Early in the acquisition process, the ranges of conditions under which the system must be effective should be clearly established by the user or the user's representative. The frequency of occurrence of adverse conditions (e.g., weather) that will limit system performance must be understood to permit acquisition decisions and appropriate planning by the Service. For each system, available data should be used to quantify the frequency of occurrence of any limiting conditions. The specified range of acceptable environmental conditions and identification of significant limiting factors should provide an important consideration in the Service's planning for the OT&E.

The system requirements documents should discuss the required operating environment.

The requirements document must address the intended operating environment for the system. Under what conditions (weather, terrain, vegetation, etc.) will the system be employed?

Limitations to system operation and/or maintenance should be projected prior to OT.

If there are any expected limitations to either the scope of operations or the system's capability, then these should be documented by the acquisition agency prior to Milestone II. The planning for operational testing should identify any environmental COIs. The OT&E needs to address the environmental conditions such that any limitation on capability due to environmental conditions is either verified or further understood and defined.

Personnel who operate and maintain the system are affected by the environment.

The ability of operators and/or maintenance personnel to function under certain environmental conditions also needs to be addressed. Personnel usually are not stressed to their endurance levels, but the impact of the weather, protective clothing, and reduced visibility may be factors that impact the efficient use of a system. If the system design requires critical personnel interaction, then consideration of these environmental areas should be part of operational test planning.

Systems with optical sensors can have limited performance in some environments.

Systems that have electro-optical, infrared, or millimeter wave seekers, or that require visual sighting by the operators, may have limitations when used in areas with high levels of obscurants, e.g., smoke, dust, etc. Any system limitations that are postulated need to be estimated and included in program planning information. The level of the limitations should be identified as a Critical Operational Issue if the limitation is critical to the eventual use of the system in its intended environment.

Environmental conditions at the OT sites usually are limited.

The sites for operational testing usually are limited by available funding. Normally there will only be one site for the early operational testing and this site is more likely to be selected for instrumentation, test facilities or ranges, or test organizations than for weather, terrain, or vegetation conditions that are representative of the intended operational environment. System requirements should clearly state if different or additional environmental conditions are important to understanding the system's operational effectiveness or suitability. For example, terrain testing is usually part of DT; if specific problems are expected with terrain or vegetation, then short operational test phases or demonstrations should be considered to address these areas.

Operational testing usually is not performed outside the system's intended environmental operating envelope.

The planning of the operational test program should address the intended operating environment and generally should not incorporate plans to operate the system outside that environment.

Operational testing may determine additional environmental limitations.

If the potential for additional limitations is great, then OT&E also must attempt to define any additional environmental limitations on the system's performance. For example, a system may be found to be not maintainable under chemical attack. If the item must be decontaminated prior to some maintenance tasks, and the capability to do this does not exist, the system has an obvious major limitation. At Milestone III, test results should be adequate to verify the level of any environmental limitation.

2.4 ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E3)

Electromagnetic Environmental Effects (E3) is defined as

the impact of the electromagnetic environment upon the operational capability of military forces, equipment, system, and platforms. It encompasses all electromagnetic disciplines, including electromagnetic compatibility/electromagnetic interference; electromagnetic vulnerability; electromagnetic pulse; electronic counter-countermeasures; hazards of electromagnetic radiation to personnel, ordnance, and volatile materials; and natural phenomena effects of lightning and p-static.

Compatibility with the electromagnetic environment is an important issue in the system's overall compatibility. E3 includes the subjects of electromagnetic interference (EMI) and electromagnetic compatibility (EMC). Within the operational suitability area, these subjects are examined as they relate to companion or friendly systems. Vulnerabilities to enemy electronic systems are addressed under operational effectiveness. To properly assess the E3 area requires the consideration of many unusual situations that may cause incompatibilities within the E3 areas. Understanding these situations requires experience and knowledge of system operation and system use in the intended operational environment. Are there unforeseen items in the environment that will cause problems with the E3 conditions? 'hat companion systems need to be considered? Are there unusual situations in the system's use that will place it with other systems that have an E3 consideration?

E3 addresses the extent to which a system's performance is degraded by electromagnetic effects due to its proximity to another electronic system. EMC and EMI are evaluated for their impact on the electromagnetic transmissions of multiple interfacing systems, as well as for their impact on friendly systems for which interfacing is not intended. Specifically, if two systems have electrical transmissions and are not in'egrated, but are brought into proximity in operational use, then consideration of their mutual operation in the presence of each other is a part of EMC. EMI addresses interference of components within the same system.

PARAMETERS

While discrete engineering parameters (e.g , spurious emission levels, radiation leakage, interference-to-noise ratios) are quantitative and measurable in the development environment, the focus during Operational Testing is at a higher total system and environment view. Parameters must be focused more on the external relationships, as well as the internal relationships. For example, Operational Testing might verify that vastly different systems and/or multiple copies of the same system can operate suitably while in close quarters at a common site. The objective of the test would be to determine if co-site interference problems exist, which would require the operator to turn one system off when using another system.

KEY POINTS

When viewed as technical considerations, E3 problems can be overcome.

The principal risk area in E3 is associated with overlooking some potential E3 condition, and then not discovering the problem until late in the development process, or until the system is fielded. DT will examine many aspects of E3. The role of operational testing is to provide a realistic E3 environment and thereby identify any potential problems that were not identified earlier in the system's development.

Susceptibility to enemy systems usually is adequately evaluated under operational effectiveness. Compatibility with friendly systems is not adequately addressed.

Adequate attention generally is given to assuring that the system being developed is not susceptible to interference from enemy or foreign equipment. Attention also must be given to compatibility with friendly systems. Examples include

- other systems that are employed by the user organization or the same military Service and are placed in proximity to the system being developed. For example, other Army systems used near the Army system under development.

- other systems that may be used in proximity to the system being developed by other military Services. For example, are there USMC or Air Force ground electronics systems that will be used in proximity to an Army ground electronics system that is being developed?

- other systems under development. Compatibility may be examined during OT&E with the systems that are existing in the operating units, but are there other systems in development that will be major factors in the E3 environment of the new system. Are these items included in the planned operational testing?

The operational testing environment needs to represent the total E3 environment to the maximum extent possible.

Complementary systems and unusual conditions need to be included in the E3 assessment.

Situations should be identified where systems are used to compliment each other in ways that are not considered the norm, but which are part of the expected system capability. Joint operations of systems by two or more of the military Services are likely to introduce situations that need to be examined. Other E3 conditions may result from operations in unusual environmental conditions (e.g., weather terrain). Surface ships operating in high sea states may have E3 environments that are different than anticipated because of the ships attitude at various times. These conditions need to be examined and considered during the planning for OT&E.

Friendly compatible systems must be identified.

The criticality of these systems must be known so that limited test resources can be focused on examining the E3 environment with these items. Does the test plan list the friendly systems to be included in the test, as well as the systems that are not? At Milestone IIIA, there will be an initial assessment of the E3 risk of the system. An early assessment may be possible by examining available E3 area technical test data. At Milestone III, the compatibility with the friendly systems should be known and the risks areas identified. The operational testing should have included all of the systems that were planned to be part of the testing.

2.5 SOFTWARE SUPPORTABILITY

For the purposes of this guide, software supportability is defined as

a measure of the adequacy of products, resources, and procedures that are needed to support the software component of a system.

Software support activities are necessary to establish an operational baseline, install the software in the system, modify or update the software, and meet the users' requirements. Software supportability is a function of the quality of the software products themselves, the capabilities of the software support resources, and the adequacy of the life cycle processes that affect the procurement, development, modification, and operational support of the software.

The criticality of the software supportability is best exemplified by the need for some system software to be periodically revised or updated to correspond to new situations. Electronic warfare systems are periodically updated as new information on threats is received or new tactics are implemented. The ability to revise the software in a timely and efficient manner can be critical to the suitability of the system to perform its required mission.

PARAMETERS

The methods for assessing the suitability of system software have evolved over the last ten years. Most of the activity by the OTAs in this area has resulted in qualitative evaluation methods using questionnaires, with the results being converted by scoring methods into quantitative measures. For example, maintainability evaluation of the software for a specific system might be scored as a "C." This means that the average qualitative evaluation of the software against a maintainability evaluation questionnaire resulted in a judgment that the software "generally agreed" with the statements in the maintainability questionnaire. A range of responses is possible: "A" = completely agree, "B" = strongly agree, "C" = generally agree, "D" = generally disagree, "E" = strongly disagree, and "F" = completely disagree.

In some software evaluations, maturity levels also are reported. The maturity levels may be expressed in the "number of software changes" or in "software change points." The term "software change points" is used when the individual software changes that are identified as being needed are weighted by the severity of their operational impact on the system. This multiplication results in a parameter termed "software change points."

KEY POINTS

The software documentation can be the key to the effective support of the software.

The timely delivery of software documentation is a key element in allowing the life cycle support activity to maintain and upgrade the software. Review of the documentation has been done in the past using a checklist approach. This approach was useful when the software was of a limited scope. However, with more complex systems, the amount of software is such that a manual, exhaustive inspection is no longer possible. Sampling techniques or other approaches that are to be used need to be identified in the TEMP and the test plan.

The maintainability of software depends on its design and arrangement.

The characteristics of the software that determine its maintainability include its modularity, descriptiveness of the software code and documentation, consistency throughout the code and documentation, simplicity, expandability (is the code built with the objective of making it easy to expand?), and instrumentation (does the code allow the easy use of testing aids?). These characteristics have been evaluated by the OTAs primarily through the use of review questionnaires. The application of the questionnaires to large software packages, the selection of samples to examine, and the relationship of the sample results to assessment of the entire system software are risk areas that need to be examined during the test planning and execution.

The interface that the software presents can be critical to system operation.

The displays, menus, etc., that the system software creates are at the critical junction between the computer-driven system and its user or maintainer. The principal evaluation methods relate to the reaction of the person to the displays. Does the software present clear and understandable information? Is there a consistency throughout the systems operation, e.g., similar menu usage, key stroking similar in similar situations, complex tasks have easily understood sequence, etc.? The evaluation of the user-software interface may be by questionnaire or by qualitative assessment at debriefings. The questionnaire method results in more consistent and perhaps more thorough evaluations, but the unstructured reaction of the personnel involved should not be ignored. Dissimilarity with the predecessor system may cause negative reactions.

The ability to maintain and modify the software depends on the adequacy of the software support resources.

Evaluation of the planned software support resources consists of the evaluation of the support personnel, support systems, and facilities that are planned. Evaluation of personnel consists primarily of identifying the number of people and the skill levels needed to provide the required support. The software support system comprises the computers and, in some cases, unique software that is needed to provide software maintenance, modification, and upgrades.

The maturity of the software can be evaluated by examining the faults or errors that have been found and the status of the individual corrective actions.

As the software is tested, errors or faults are found. Some OTAs evaluate each software fault (i.e., weight each fault by the severity of the effect on the system) and produce a plot of the cumulative number changes, or change points, against the amount of testing that has been performed. This curve generally shows an increasing number of faults as the software is exercised, followed by a decreasing rate indicating that most of the faults have been found. The use of severity weighting assures that inordinate weight is not given to a number of minor faults, while major faults are ignored. The plot of software maturity can give a clear view of when the software is reaching a maturity, when it is reasonable to start OT, and when the software is mature enough to enter the operational inventory. The DOT&E staff assistant should be familiar with this software maturity technique if it is to be used on one of the assigned programs.

Software maturity depends on testing exposure.

The assessment of the maturity of the software depends on the thoroughness of the software testing. Are all software capabilities being tested? Are the low probability paths, as well as the nominal conditions, being exercised? Are error routines and fault identification modules being included in the testing? To accurately judge the maturity of the software, an attempt should be made to assure that all aspects of the software are included in the test.

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Chapter 3

SERVICE OTAs COMMON RELIABILITY, AVAILABILITY, AND MAINTAINABILITY (RAM) TERMINOLOGY

The Military Services Operational Test and Evaluation Agencies (OTAs) have agreed to common methods to be used during testing that involve more that one Service. This is defined as Multi-Service OT&E. In 1989, the four Service OTAs agreed to a listing of "Common Reliability, Availability and Maintainability Terms for use in Multi-Service OT&E Test Programs." This listing is contained in Annex A to the OTAs Memorandum of Agreement and is included in the Operational Suitability Guide for reference.

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ANNEX A

COMMON RELIABILITY, AVAILABILITY, AND
MAINTAINABILITY (RAM) TERMINOLOGY

1. <u>Purpose</u>. This Annex provides the policy and common RAM
terminology for the quantitative portion of MOT&E suitability
evaluations.

2. <u>Background</u>. MOT&E common terms are intended to convey the
same meaning to all Services. Therefore, they avoid terms used
elsewhere with different meanings. Existing terms used by one
or more Services were selected when possible. Table A-1 com-
pares the RAM terms to be used for multiservice testing, as
described in this Annex, with the relative service-unique RAM
terms currently in use. Other relevant, service-unique RAM
terms are provided in appendices to this Annex.

3. <u>Policy</u>

    a. Common terms described in this Annex will be used as
appropriate in multiservice test reports. If additional terms
are necessary, they should be agreed upon and clearly defined
by all participating agencies.

    b. Multiservice terms selected will be included in the
multiservice TEMP.

4. <u>Common RAM Terms for MOT&E</u>

    a. <u>Reliability</u>. Reliability consists of two major areas:
mission reliability and logistics support frequency.

        (1) Mission reliability is the probability a system can
complete its required operational mission without an operational
mission failure (OMF). An OMF is a failure that precludes
successful completion of a mission, and must be specifically
defined for each system. For some systems, mission reliability
may be better expressed as Mean Time (miles, rounds, etc.)
Between Operational Mission Failure (MTBOMF). (See paragraph 5
for definition.)

        (2) Logistics support frequency is a representative
time between incidents requiring unscheduled maintenance,
unscheduled removals, and unscheduled demands for spare parts,
whether or not mission capability is affected. Logistics sup-
port frequency may be expressed as Mean Time Between Unscheduled
Maintenance (MTBUM). (See paragraph 5 for definition.)

b. <u>Maintainability</u>. Maintainability consists of three major areas: OMF repair time, corrective maintenance time, and maintenance ratio. Maintainability may be expressed as (1) Mean Operational Mission Failure Repair Time (MOMFRT), (2) Mean Corrective Maintenance Time (MCMT), (3) Maximum Time To Repair (MaxTTR), and (4) various maintenance ratios, e.g., Maintenance Man-Hours Per Operating Hour, Mile, Round, etc. (See paragraph 5 for definitions.)

c. <u>Availability</u>. Operational availability (A_o) is the probability that a system will be ready for operational use when required. (See paragraph 5 for definition.)

d. <u>Diagnostics</u>. Diagnostics addresses the ability of integrated diagnostics (automated, semi-automated, and manual techniques taken as a whole) to fault-detect and fault-isolate in a timely manner. Diagnostics may be expressed as (1) the percent of correct detection given that a fault has occurred (P_{cd}), and (2) Mean Time To Fault Locate (MTTFL). (See paragraph 5 for definitions.)

5. <u>Definitions for Multiservice Terms</u>

a. <u>Mean Time Between Operational Mission Failures (MTBOMF)</u>: The total operating time (e.g., driving time, flying time, or system-on time) divided by the total number of OMFs.

b. <u>Mean Time Between Unscheduled Maintenance (MTBUM)</u>: The total operating time divided by the total number of incidents requiring unscheduled maintenance.

c. <u>Mean Operational Mission Failure Repair Time (MOMFRT)</u>: The total number of clock-hours of corrective, on-system, active repair time, which is used to restore failed systems to mission-capable status after an operational mission failure (OMF) occurs, divided by the total number of OMFs.

d. <u>Mean Corrective Maintenance Time (MCMT)</u>: The total number of clock-hours of corrective, on-system, active repair time due to all corrective maintenance divided by the total number of incidents requiring corrective maintenance.

e. <u>Maximum Time To Repair (MaxTTR)</u>: That time below which a specified percentage of all corrective maintenance tasks must be completed.

f. <u>Maintenance Man-Hours Per Operating Hour (MMH/OH)</u>: The cumulative number of maintenance man-hours during a given period divided by the cumulative number of operating hours. If appropriate, other terms such as miles or rounds may be sub-

stituted for hours. Scheduled as well as corrective main-
tenance, in keeping with the users maintenance requirements,
are included without regard to their effect on mission or
availability of the system.

g. Operational Availability (Ao): A_o is either the total
uptime divided by the uptime plus downtime when operated in an
operational mission scenario, or the number of systems that are
ready divided by the number possessed.

h. Percent of Correct Detection Given That a Fault Exists
(Pcd): The number of correct detections divided by the total
number of confirmed faults.

i. Mean Time To Fault Locate (MTTFL): The total amount of
time required to locate faults divided by the total number of
faults.

APPENDICES:

1 – Army Terms and Definitions
2 – Navy Terms and Definitions
3 – Marine Corps Terms and Definitions
4 – Air Force Terms and Definitions

TABLE A-1.   COMPARISON OF MULTISERVICE AND SERVICE-UNIQUE TERMS

CATEGORY	MULTI-SERVICE	ARMY	NAVY	AIR FORCE	MARINES
RELIABILITY	MTBOMF MTBUM	MTBOMF MTBUMA	MTBMCF MTBF	MTBCF MTBME	MTBOMF MTBUMA
MAINTAINABILITY	MOMFRT MCMT MaxTTR MMH/OH	NONE MTTR MaxTTR MR	MTTR NONE NONE DMMH/FH	NONE MRT MaxTTR MMH/OH	NONE MTTR MaxTTR MR
AVAILABILITY	A_o	A_o	A_o	A_o AND OTHERS	A_o
DIAGNOSTICS	P_{cd} MTTFL	P_{cd} AND OTHERS	P_{cd} AND OTHERS	P_{cd} AND OTHERS	P_{cd} AND OTHERS

APPENDIX 1

ARMY TERMS AND DEFINITIONS

1. **Purpose.** This Appendix provides the RAM terms and definitions most relevant to this Ann x and used within the Army in conducting and reporting OT&E activity in accordance with AR 702-3. They are included in the Memorandum of Agreement so as to assist other Services in understanding RAM terms as used by the Army. Terms used by other Services are included in Appendices 2, 3, and 4.

2. **Definitions**

   a. **Durability:** A special case of reliability; the probability that an item will successfully survive to its projected life, overhaul point, or rebuild point (whichever is the more appropriate durability measure for the item) without a durability failure. (See Durability Failure.)

   b. **Failure:** The event, or inoperable state, in which an item or part of an item does not, or would not, perform as previously specified. (See MIL-STD 721.)

   c. **Failure, Critical:** A failure (or combination of failures) that prevents an item from performing a specified mission. (Note: Normally only one failure may be charged against one mission. Critical failure is related to evaluation of mission success.)

   d. **Failure, Durability:** A malfunction that precludes further operation of the item, and is great enough in cost, safety, or time to restore, that the item must be replaced or rebuilt.

   e. **Failure Mode:** The mechanism through which failure occurs in a specified component (for example, short, open, fatigue, fracture, or excessive wear). (See MIL-STD 721.)

   f. **Inherent RAM Value:** Any measure of RAM that includes only the effects of an item design and its application, and assumes an ideal operating and support environment.

   g. **Maintainability:** A measure of the ability of an item to be retained in, or restored to, a specified condition when maintenance is performed by personnel having specified skill levels using prescribed procedures and resources.

   h. **Maintenance Ratio (MR):** A measure of the maintenance manpower required to maintain a system in an operational envi-ronment. It is expressed as the cumulative number of direct

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maintenance man-hours (see AR 570-2) during a given period, divided by the cumulative number of system life units (such as hours, rounds, or miles) during the same period. The MR is expressed for each level of maintenance and summarized for combined levels and maintenance. All maintenance actions are considered (that is, scheduled as well as corrective, and without regard to their effect on mission or availability of system). Man-hours for off-system repair of replaced components are included in the MR for the respective level.

i. <u>Maximum Time To Repair (MaxTTR)</u>: That time below which a specified percentage of all corrective maintenance tasks must be completed. When stated as a requirement, the MaxTTR should be stated for organizational and direct support levels of maintenance. MaxTTR is used as an "on-system" maintainability parameter; it is not used for the off-system repair of replaced components.

j. <u>Mean Time Between Essential Maintenance Actions (MTBEMA)</u>: For a particular measurement interval, the total number of system life units divided by the total number of nondeferrable maintenance actions. This parameter indicates the frequency of demand for essential maintenance support and includes incidents caused by accidents, maintenance errors, and item abuse. (Not included are crew maintenance completed within a specified number of minutes, maintenance deferrable to the next scheduled maintenance, system modification, and test-peculiar maintenance.)

k. <u>Mean Time Between Operational Mission Failure (MTBOMF)</u>: A measure of operational effectiveness that considers the inability to perform one or more mission-essential functions.

l. <u>Mean Time Between Unscheduled Maintenance Actions</u>: Computed by the following formula:

$$MTBUMA = \frac{\text{Operating time}}{\text{Total number of unscheduled maintenance actions}}$$

m. <u>Mean Time To Repair (MTTR)</u>: The sum of corrective maintenance times divided by the total number of corrective maintenance actions during a given period of time under stated conditions. MTTR may be used to quantify the systems maintainability characteristic. MTTR applies to the system-level configuration; it will be used as an "on-system" maintainability index and not for the repair of components. MTTRs will be stated for the unit and the intermediate direct support levels of maintenance along with the percentage of actions repaired at each level.

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n. **Mission Reliability (Rm)**: A measure of operational effectiveness. It is stated in terms of a probability of completing a specified mission profile or the mean time (or distance or rounds) between critical failures.

o. **Mission-Essential Functions**: The minimum operational tasks that the system must be capable of performing to accomplish its mission profiles.

p. **Off-System Maintenance**: Maintenance associated with the diagnosis and repair of components for return to stock.

q. **On-System Maintenance**: Maintenance necessary to keep a system in, or return a system to, an operating status.

r. **Operational Availability**: The proportion of time a system is either operating, or is capable of operating, when used in a specific manner in a typical maintenance and supply environment. All calendar time when operating in accordance with wartime operational mode summary/mission profile (OMS/MP) is considered. The formula is as follows:

$$A_O = \frac{OT + ST}{OT + ST + TCM + TPM + TALDT}$$

$$= \frac{\text{Total calendar time minus total downtime}}{\text{Total calendar time}}$$

Where: OT = The operating time during OMS/MP

ST = Standby time (not operating, but assumed operable) during OMS/MP

TCM = The total corrective maintenance downtime in clock-hours during OMS/MP

TPM = The total preventive maintenance downtime in clock-hours during OMS/MP

TALDT = Total administrative and logistics downtime (caused by OMFs) spent waiting for parts, maintenance personnel, or transportation during OMS/MP

Other forms of this equation are substituted depending on the system type (see AMC/TRADOC PAM 70-11) such as the inclusion of relocation time.

s. **Operational Mission Failure (OMF)**: Any incident or malfunction of the system that causes (or could cause) the

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inability to perform one or more designated mission-essential functions.

t. <u>Operational RAM Value</u>: Any measure of RAM that includes the combined effects of item design, quality, installation, environment, operation, maintenance, and repair. (This measure encompasses hardware, software, crew, maintenance perso..nel, equipment publications, tools, TMDE, and the natural, operating, and support environments.

u. <u>Reliability</u>: The probability that an item can perform its intended functions for a specified time interval under stated conditions.

v. <u>Reliability After Storage</u>: This may be a stated requirement. If appropriate, it specifies the amount of deterioration acceptable during storage. Length of storage, storage environment, and surveillance constraints are identified. This requirement may not be testable; it may rely on an engineering analysis for its assessment before deployment.

w. <u>System Readiness Objective (SRO)</u>: One of a group of measures relating to the effectiveness of an operational unit to meet peacetime deployability and wartime mission require-ments considering the unit set of equipages and the potential support assets and resources available to influence the units operational readiness and sustainability. Peacetime and wartime SROs will differ due to usage rate, OMS/MPs, and operational environments. Examples of SROs include: operational availability at peacetime usage rates, operational availability at wartime usage rates, sortie generations per given time frame (aircraft), and maximum ALDT (intermittent mission). SROs must relate quantitatively to system design parameters (RAM) and relate to support resource requirements. (See AR 700-127.)

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APPENDIX 2

NAVY TERMS AND DEFINITIONS

1. Purpose. This Appendix provides the RAM terms and
definitions most relevant to this Annex and used within the
Navy in conducting and reporting OT&E activity in accordance
with COMOPTEVFORINST 3960.1E. They are included in the
Memorandum of Agreement so as to assist other services in
understanding RAM terms as used by the Navy. Terms used by
other services are included in Appendices 1, 3, and 4.

2. Definitions

    a. Availability: A measure of the degree to which an item
is in an operable and committable state at the start of a
mission when the mission is called for at an unknown (random)
time. In OT&E, operational availability (A_o) is the usual
measure. (See Operational Availability.)

    b. Failure, Critical: One that prevents the system from
performing its mission or results in the loss of some
significant mission capability.

    c. Failure, Minor: One that affects system performance
but does not impact the ability to perform the mission.

    d. Maintainability: The capability of an item to be
retained in or restored to specified conditions when
maintenance is performed by personnel having specified skill
levels, using prescribed procedures and resources, at each
prescribed level of maintenance and repair. MTFL, MTTR, and
MSI are frequently calculated in maintainability evaluations.

    e. Maintenance Support Index (MSI): The ratio of total
man-hours required for maintenance (preventive plus corrective)
to the total operating (up) time. Frequently computed as part
of Test S-2 Maintainability.

    f. Mean Flight Hours Between Failure/Mean Time Between
Failure (MFHBF/MTBF): See Reliability.

    g. Mean Time To Fault-Locate (MTFL): The total fault-
location time divided by the number of critical/major failures.
Frequently computed as part of Test S-2 Maintainability.

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h. **Mean Time To Repair (MTTR)**: Normally computed as part of maintainability, MTTR is the average time required to perform active corrective maintenance. Corrective maintenance is the time during which one or more personnel are repairing a critical or major failure and includes: preparation, fault location, part procurement from local (on-board) sources, fault correction, adjustment/calibration, and follow-up checkout times. It excludes off-board logistic delay time.

i. **Mission Reliability**: See Reliability.

j. **Operational Availability**: (See Availability for basic definition.) Operational availability is computed and reported as follows:

(1) **Continuous-Use Systems**: Operational availability shall be designated A_o and shall be determined as the ratio of system "uptime" to system "uptime plus downtime."

(2) **"On-Demand" Systems**: Operational availability shall be designated A_{od} and shall be determined as the ratio of the "number of times the system was available to perform as required to the total number of times its performance was required." (Note: "Total number of times its performance was required" shall be the number of times attempted and the number of times it was operationally demanded but not attempted because the system was known to be inoperable.)

(3) **Impulse Systems**: Operational availability shall be designated A_{oi}, and since A_{oi} and R are inseparable during testing, only reliability (R) shall be reported.

k. **Operational Effectiveness**: The capability of a system to perform its intended function effectively over the expected range of operational circumstances, in the expected environment, and in the face of the expected threat, including counter-measures where appropriate.

l. **Operational Suitability**: The capability of the system, when operated and maintained by typical fleet personnel in the expected numbers and of the expected experience level, to be reliable, maintainable, operationally available, logistically supportable when deployed, compatible, interoperable, and safe.

m. **Reliability**: The duration or probability of failure-free performance under stated conditions. In OT&E, reliability is usually reported in one of two ways:

(1) **Mean Time Between Failure (MTBF)**: For more-or-less continuously operated equipment, the ratio of total operating time to the sum of critical and major failures. MTBF is

sometimes modified to mean flight hours between failures (MFHBF).

       (2) <u>Mission Reliability</u>: For equipment operated only during a relatively short-duration mission (as opposed to equipment operated more-or-less continuously), the probability of completing the mission without critical or major failure. Frequently expressed as exp (-t/MTBF), where "t" is mission duration and MTBF is as defined above.

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APPENDIX 3

MARINE CORPS TERMS AND DEFINITIONS

1. **Purpose**. This Appendix provides the RAM terms and definitions most relevant to this Annex and used within the Marine Corps in conducting and reporting OT&E activity in accordance with FMFM 4-1 (Combat Service Support), TRADOC/AMC Pamphlet 70-11 (RAM Rationale Report Handbook), and DoD 3235.1-H (Test and Evaluation of System Reliability, Availability, and Maintainability, a Primer). They are included in the Memorandum of Agreement so as to assist other services in understanding RAM terms as used by the Marine Corps. Terms used by other services are included in Appendices 1, 2, and 4.

2. **Definitions**

   a. **Achieved Availability (Aa)**: Computed with the following formula:

$$A_a = \frac{OT}{OT + TCM + TPM}$$

Where: OT = Operating time
       TCM = Total corrective maintenance
       TPM = Total preventive maintenance

   b. **Administrative and Logistics Downtime (ALDT)**: The period of time that includes (but is not limited to) time waiting for parts, processing records, and transporting equipment and/or maintenance personnel between the using unit and repair facility.

   c. **Corrective Maintenance (CM)**: Maintenance that is performed on a nonscheduled basis to restore equipment to satisfactory condition by correcting a malfunction (unscheduled maintenance). The measure is Total Corrective Maintenance (TCM) time.

   d. **Depot Level Maintenance**: Maintenance that is performed by designated industrial-type activities using production-line techniques, programs, and schedules. The principal function is to overhaul or completely rebuild parts, subassemblies, assemblies, or the entire end item.

   e. **Essential Maintenance Action (EMA)**: Maintenance that must be performed prior to the next mission. This includes correcting operational mission failures, as well as performing certain unscheduled maintenance actions.

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f. <u>Failure</u>: Any single, combination, or summation of hardware or software malfunctions that cause a maintenance action to be performed.

g. <u>Inherent Availability (Ai)</u>: Computed with the following formula:

$$A_i = \frac{OT}{OT + TCM}$$

h. <u>Intermediate Level Maintenance (ILM)</u>: Maintenance that is authorized by designated maintenance activities in support of using organizations. The principal function of ILM is to repair subassemblies, assemblies, and major items of equipment for return to a lower echelon or to supply channels. Measures are as follows:

    (1)   MTTR at ILM

    (2)   MaxTTR at ILM

i. <u>Maintenance Ratio (MR)</u>: Computed by the following formula:

$$MR = \frac{\text{Total man-hours of maintenance}}{\text{Operating time}}$$

j. <u>Maximum Time To Repair (MaxTTR)</u>: That time below which a specified percentage of all corrective maintenance tasks must be completed.

k. <u>Mean Time Between Operational Mission Failure (MTBOMF)</u>: Computed by the following formula:

$$MTBOMF = \frac{\text{Operating time}}{\text{Total number of operational mission failures}}$$

l. <u>Mean Time Between Unscheduled Maintenance Actions (MTBUMA)</u>: Computed by the following formula:

$$MTBUMA = \frac{\text{Operating time}}{\text{Total number of unscheduled maintenance actions}}$$

m. <u>Mean Time To Repair (MTTR)</u>: Computed by the following formula:

$$MTTR = \frac{\text{Total corrective maintenance time}}{\text{Total number of corrective maintenance actions}}$$

n. Operational Availability (Ao): Computed by the
following formula:

$$A_O = \frac{OT + ST}{OT + ST + TCM + TPM + TALDT}$$

Where: OT = Operating time
         ST = Standby time
        TCM = Total corrective maintenance time
        TPM = Total preventive maintenance time
      TALDT = Total administrative and logistics downtime

o. Operating Time (OT): The period of time that the
system is powered and capable of performing a mission-essential
function.

p. Operational Mission Failure (OMF): A failure that
reduces the capability of the system to a point where one (or
more) mission essential function(s) cannot be performed.
Measures are as follows:

          (1)   Mean time between OMF (MTBOMF),

          (2)   Mean miles between OMF (MMBOMF), and

          (3)   Mean rounds between OMF (MRBOMF).

q. Organizational Level Maintenance (OLM): Maintenance
that is authorized for, performed by, and the responsibility of
a using organization on its own equipment. Measures are as
follows:

          (1)   MTTR at OLM, and

          (2)   MaxTTR at OLM.

r. Preventive Maintenance (PM): The actions performed to
retain an item in a specified condition by systematic
inspection, detection, and prevention of incipient failures.
The measure is Total Preventive Maintenance (TPM) time.

s. Percent of Correct Detection: Percent of all faults or
failures that the BIT system detects.

t. Scheduled Maintenance: Maintenance that is performed
on a regular basis over the life of a system in order to
maintain its ability to perform mission essential functions.
This maintenance consists of programmed services and/or
replacements performed at intervals defined by calender time or
usage (i.e., miles, hours, rounds...).

u. <u>Standby Time (ST)</u>: The period of time that the system is presumed operationally ready for use, but does not have power applied, is not being operationally employed, and no PM or CM is being performed.

v. <u>Time To Repair</u>: A representative time of the effort expended on corrective maintenance. Measures are as follows:

    (1)   Mean time to repair (MTTR), and

    (2)   Maximum time to repair (MaxTTR).

w. <u>Unscheduled Maintenance</u>: Maintenance that was not programmed, but is required to restore the item to partial or full mission capability.

APPENDIX 4

AIR FORCE TERMS AND DEFINITIONS

1. Purpose. This Appendix provides the RAM terms and
definitions which are most relevant to this Annex and used
within the Air Force in conducting and reporting OT&E
activity. They have been extracted from AFR 55-43, AFP 57-9,
and DoD 3235.1-H (Test and Evaluation of System Reliability,
Availability, and Maintainability). They are included in the
Memorandum of Agreement so as to assist other services in
understanding RAM terms as used by the Air Force. Terms used
by other services are included in Appendices 1, 2, and 3.

2. Definitions

   a. Break Rate: The percent of time an aircraft will
return from an assigned mission with one or more previously
working systems or subsystems on the Mission-Essential
Subsystem List (MESL) inoperable (code 3 including ground and
air aborts). Repairs must be made before the aircraft can
perform a subsequent "like-type" mission.

   b. Fix Rate: The percent of aircraft, which return "code
3" from an assigned mission, that must be repaired in a
specified number of clock-hours, i.e., 70 percent in 4 hours.
Fix rate is similar to mean downtime. The time requirement for
fix rate includes direct maintenance time and downtime
associated with maintenance policy and administrative and
logistics delays.

   c. Maintainability: The ability of an item to be retained
in or restored to specified conditions when maintenance is
performed by personnel having specified skill levels, using
prescribed procedures and resources, at each prescribed level
of maintenance and repair.

   d. Maintenance Man-Hours/Operating Hour (MMH/OH): The
number of base-level, direct maintenance man-hours required to
support a system divided by the number of operating hours
during the period. Where aircraft, ships, and vans are
involved, maintenance man-hours/flying hour (MMH/FH), main-
tenance man-hours/sortie (MMH/S), or some similar requirement
may be used.

   e. Maximum Time To Repair (MaxTTR): The time within which
a specified percentage of all corrective maintenance tasks must
be completed. For example, 90 percent of all corrective
maintenance actions must be completed within two hours.

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f. Mean Repair Time (MRT): The average on- or off-equipment corrective maintenance time in an operational environment. MRT starts when the technician arrives at the system or equipment for on-equipment at the system level, and off-equipment at the assembly, subassembly, module, or circuit card assembly at the off-equipment repair location. The time includes all maintenance actions required to correct the malfunction, including preparing for test, troubleshooting, removing and replacing components, repairing, adjusting, and functional check. MRT does not include maintenance or supply delays. MRT is similar to MTTR, but is referred to as MRT when used as an operational term to avoid confusion with the contractual term of MTTR.

g. Mean Downtime (MDT): The average elapsed clock-time between loss of mission-capable status and restoration of the system to mission-capable status. This downtime includes maintenance and supply response, administrative delays, and actual on-equipment repair. In addition to the inherent repair and maintainability characteristics, mean downtime is affected by technical order availability and adequacy, support equipment capability and availability, supply levels, and manning. Thus, MDT is not the same as the contractual term mean time to repair (MTTR).

h. Mean Time Between Critical Failures (MTBCF): The average time between failure of essential system functions. For ground electronic systems, MTBCF is equal to the total equipment operating time in hours divided by the number of failures of essential systems required for completion of the assigned mission. MTBCF includes both hardware and software failures.

i. Mean Time Between Maintenance Events (MTBME): The average time between on-equipment, corrective events including inherent, induced, no-defect, and preventive maintenance actions. It is computed by dividing the total number of life units (for example, operating hours, flight hours, rounds) by the total number of maintenance (base level) events for a specific period of time. A maintenance event is composed of one or more maintenance actions.

j. Mean Time Between Removal (MTBR): A measure of the system reliability parameter related to demand for logistic support. The total number of system life units divided by the total number of items removed from that system during a stated period of time. This term is defined to exclude removals performed to facilitate other maintenance and removals for time compliance technical orders (TCTOs).

k. Mission-Capable (MC) Rate: The percent of possessed time that a weapons system is capable of performing any of its assigned missions. The MC rate is the sum of the full mission-capable (FMC) and partial mission-capable (PMC) rates.

1. <u>Operational Availability</u>: The ability to commit a
system or subsystem to operational use when needed, typically
stated in terms of A_o, mission-capable rate, sortie generation
rate, or uptime ratio. For systems with a defined mission
duration, it does not indicate the capability to complete a
mission once the mission begins.

m. <u>Percent BIT Can-Not-Duplicate (CND)</u>: A BIT CND is an
on-equipment, BIT indication of a malfunction that cannot be
confirmed by subsequent troubleshooting by maintenance
personnel. It is computed with the following formula:

$$\% \text{ CND} = \frac{\text{Number of BIT CND}}{\text{Total number of BIT indications*}} \times 100$$

*Excludes false alarms that do not generate maintenance
actions.

n. <u>Percent BIT False Alarm (FA)</u>: A BIT FA is an
indication of a failure that is not accompanied by system
degradation or failure and, in the opinion of the operator,
does not require any maintenance action. It is computed by the
following formula:

$$\% \text{ FA} = \frac{\text{Number of BIT indications not resulting in maintenance actions}}{\text{Total number of BIT indications}} \times 100$$

o. <u>Percent BIT Fault Detection (FD)</u>: Measures instances
where a confirmed failure is a condition when equipment
performance (including BIT performance) is less than that
required to perform a satisfactory mission, and corrective
action is required to restore equipment performance. The
formula below assumes that a requirement exists for 100-percent
diagnostics capability.

$$\% \text{ BIT FD} = \frac{\text{Number of confirmed failures detected by BIT}}{\text{Number of confirmed failures detected via all methods}} \times 100$$

p. <u>Percent Fault Isolation (FI)</u>: It is just as opera-
tionally valuable for BIT to fault-isolate an aircrew-reported
fault, or manually detected fault, as it is for BIT to fault-
isolate BIT-detected faults. Effective isolation means that
the fault is unambiguously isolated to a single-item node
(driver, receiver, connector, wire) or to a specified maximum

number of items (an ambuiguity group of x items). The formula
below defines the percent of FI.

$$\% \; FI = \frac{\text{Number of fault isolations in which BIT effectively contributed}}{\text{Number of confirmed failures detected via all methods}} \times 100$$

q. <u>Percent Retest OK (RTOK)</u>: Defined by the formula below
as follows:

$$\% \; RTOK = \frac{\text{Number of units (LRU, SRU) that RTOK at a higher maintenance level}}{\text{Number of units removed as a result of BIT}} \times 100$$

r. <u>Uptime Ratio (UTR)</u>: The percentage of time that
operational equipment is able to satisfy mission demands. UTR
is similar to MC, except that system status depends on current
use of the system, as well as the designated operational
capability (DOC). For example, a system with several DOC
missions can be MC if at least one of those missions can be
accomplished. However, if an immediate need exists for a
mission capability that is "down", the overall system is
considered to be "down."

s. <u>Weapon System Reliability (WSR)</u>: The probability that
a system will complete a specified mission given that the
system was initially capable of doing so.